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THE ELEMENTS OF GEOGRAPHY

GENERAL GEOGRAPHY.

J.H.N. STEPHENSON.

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J. H. N. STEPHENSON, M.A.

PART I

GENERAL GEOGRAPHY

WITH ILLUSTRATIONS AND MAPS

LONDON: EDWARD STANFORD
12, 13, & 14, LONG ACRE, W.C.
1908

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PREFACE

THE appearance of any addition to the ever-growing 'Babel' of text-books seems to require strong justification. Briefly, then, the author's plea for this rests on the attempt to co-ordinate 'Physical' and 'Regional' Geography; and in the First Part now issued, more particularly to establish a real link between the two, by the aid of what may be called the 'organic sciences.'

Formerly, the existing manuals of geography confined themselves to an array of facts, some important, others trivial, but all alike set forth with complete indifference to any vital connexion between them, as well as disregard of their relative values. Thus a strip of barren rock was more important than miles of fertile plain, because it happened to stretch out into the sea; and the population of a town was stated, without any reason for the existence of the town at all. And since this proved a somewhat indigestible fare—so much so, indeed, that to this day the subject is absolutely 'taboo' in some of our leading public schools—an almost pathetic attempt was made to render it more palatable by startling variations of type, which only demonstrated too plainly the lack of logical cohesion.

Later it became the fashion to preface the main portion of the book, treating of Regional Geography, with introductory remarks on Physiography; though here, again, the items of information given were strangely disproportionate to their relative importance. Thus the fact that the earth is not a sphere, but an oblate spheroid, was always religiously dwelt on, and the formation of stalagmites and stalactites explained with loving care and minuteness; while such important problems, as why some parts of the globe are mountainous and others flat, why Canada grows wheat, and large tracts of the Sahara nothing, were discreetly let alone. In a word, attention was everywhere directed to the abnormal rather than to normal phenomena.

But of late Physical and Regional Geography have parted company, and the former, at least, has been illumined by an almost bewildering number of text-books by master hands; but if it has been a decided gainer, Regional Geography has for the most part been left, so far as elementary text-books are concerned, to the mercy of the printer with the largest assortment of type. A further defect in the present system is, that only the inorganic side of Physical Geography is generally considered under that head, and so the connecting link with the 'applied' branch of the study, supplied by such sciences as Physiology and Economics, is too often entirely lost sight of. Yet it is hardly too much to claim for geography that, rightly treated, it is the ideal foundation for the study of the social as well as the natural sciences.

While, therefore, it would be as futile as impertinent for the present writer to attempt to compete with the manuals of such pre-eminent authorities as T. H. Huxley and Professor Geikie, he has been obliged with their aid to stumble along the path they have marked out, in order to reach the comparatively untrodden ground beyond, where unfortunately their masterly guidance is no longer available.

In this connexion the author must acknowledge his debt to such suggestive handbooks as Sir Robert Ball's 'The Earth's Beginning,' Mr. A. T. Simmons's 'Physiography for

Beginners,' and Dr. Fream's 'Elements of Agriculture,' as well as to the works of Professor Geikie and numerous articles in the 'Encyclopædia Britannica.' The chapter on 'Races of Mankind' is mainly based on Mr. E. B. Tylor's 'Anthropology'; while Dr. H. R. Mill's 'Elementary Commercial Geography' and the companion atlas, Diercke's 'Schul-Atlas,' and Professor von Juraschek's 'Geographisch-statistische Tabellen,' have been invaluable for reference.

That the present work is full of imperfections, its author is only too well aware; but if it in any way contributes to placing the study of Regional Geography on a more rational basis, and establishing its vital connexion with what is commonly known as Physical Geography, its shortcomings will perhaps meet with indulgence.

One last point demands notice. It has been the writer's aim throughout to explain each phenomenon dealt with in the simplest possible language, and only after this has been done, sometimes more than once, to give it a 'scientific label'; for experience has long convinced him that such names tend to frighten the beginner, and destroy his interest in the subject, to an extent which only those who have constantly taken boys in low forms can possibly realise. Hence no apology is offered for the frequent use of 'you' and 'we,' and of other colloquialisms; nor has any attempt been made at elegance of style, since only a favoured few have the art of making the simplest English clearly, and at the same time gracefully, express unfamiliar ideas.

J. H. N. S.

LETCHWORTH SCHOOL,
January 1908.

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THE
ELEMENTS OF GEOGRAPHY

INTRODUCTION

§ 1. GEOGRAPHY tells us about the Earth we live in; and as almost every kind of fact connected with the earth has been made a special study, or *science*, we shall have to learn something of many of these sciences, in order to find out all we want to know about it.

And first of all we must try to look at the earth from outside, as it were, and understand its position and movements amongst the other bodies in space. For this we shall want *Astronomy* to help us, and so this part of our subject is called *Astronomical Geography*.

Then we shall consider the solid earth, or at least the thin film or crust which forms its outer layer, and learn as well as we can what it is made of, and how it came to be as it is now, with different kinds of rock and soil, and the endless variety of mountain, valley and plain. For this we must turn to *Geology*. Next, we must learn something about the air which wraps the earth round, and its movements, called winds, with their effect on climate: this is the science of *Meteorology*. Then about the many forms of water—which is the life-blood of our earth, penetrating all things, and disappearing from one place only to reappear in another—and about the sea with its ceaseless movements of wave, tide and current. All that we have gathered about the land, air and water will be included under the head of *Inorganic Geography.*

§ 2. We shall then be able to understand more about the plants and animals that live on the earth, because these depend on soil and climate, and to study their relation to ourselves, especially in serving as food for us. The science that deals with the living things of the earth as a whole is *Physiology.* After this we shall need to know something of the principles on which we supply one another's various wants; some by getting materials in one form or another from the earth, others in manufacturing the materials into useful things, others again distributing the things, when they are made, to different places in exchange for other things. The science which explains this to us is called *Economics.*

Then, again, we must consider the various kinds of human beings, or races of men, that inhabit different parts of the earth, and what the main differences are which mark them off one from another. This is the science of *Ethnology.* This part of our subject which deals with living things, whether plants, animals, or men, may be called *Organic Geography.*

Finally, we must get a clear idea of how the main features of the earth, or any part of it, are expressed on paper by means of maps, and this is the science of *Cartography.*

§ 3. So far we shall have considered the earth as a whole, and our First Part was therefore called 'General Geography.' In the Second Part we shall study different parts of it, or *regions*; and so this division of the subject is called 'Regional Geography.' This we shall do by first applying what we have learnt in the First Part, of Astronomical, Inorganic, and Organic Geography, in order to understand the special features or characteristics of each of these regions; as, for example, its shape, its mountains, plains and rivers, its climate, the plants and animals that best flourish on it, and the races of mankind that inhabit it. All this is included in the *Physical Geography* of the region. Next, we must apply what we have learnt of Economics, to see how the majority of its inhabitants are employed; what they are able to give to other regions, and what they get from those regions in return. This is its *Economic Geography.* Last, we must call in History to help us to understand how different regions come to be governed under separate laws, and so form *countries* or *states,* in many cases speaking different languages; and what the boundaries are between the various states. This comes under the head of *Political Geography.*

The following table will help to make the relation of all these sciences to the various divisions of Geography, and the relation of these one to another, more clear to you:—

A TABLE ILLUSTRATING THE SCOPE AND DIVISIONS OF GEOGRAPHY

Part I. General Geography.	Astronomical,	dealing with	Astronomy.
	Inorganic	,, ,,	Geology. Meteorology. Science of water.
	Organic	,, ,,	Physiology. Economics. Ethnology.
	Cartographical	,, ,,	Cartography.
Part II. Regional Geography.	Physical. Economic. Political.		

Questions on the Introduction.

1. Mention the chief divisions of Geography, and state clearly the object of each.

2. What is meant by a ‘science’? How do those of Meteorology and Ethnology concern Geography?

3. What is a country? How would you set about learning its Geography?

A. ASTRONOMICAL GEOGRAPHY

CHAPTER I

THE EARTH IN SPACE

§ 4. If we want to know about a person or an animal or plant, or, indeed, almost anything, we naturally try to find out something of its surroundings. In the same way it will help us to know more about the earth if we learn something of its surroundings, and can fit it, so to speak, into its place in what we call the *universe*.

Once it was thought that the earth was a vast flat surface, round which circled the smaller bodies seen in the sky. In time men came to realise that the earth, great as it is, was quite small and insignificant compared with these bodies; that, like them, it was round, not flat, and that it was really the earth that turned round and round, making the heavens seem to be moving in the opposite direction, just as when we are in a railway train everything outside the carriage window seems to be moving backwards. Gradually, too, by the help of wonderful instruments and difficult reckonings, more and more was learnt of the nature and movements of the heavenly bodies and of the earth itself; so that we know now that the stars are all bodies something like the sun, and are made of much the same materials as our own earth, but white hot, or, as it is called, *incandescent*, like the wire in an electric lamp. Many of them—indeed, most of those we see in the sky at night—are even bigger and brighter than the sun, and only give us less light because they are so much farther away that it is almost hopeless to try and imagine the distances.

§ 5. Coming now to the earth, we see at once that it is something very different from the sun and the other stars. It is not incandescent, or we could not live on it, any more than we could in a furnace, though we shall find later that it is hot enough inside. The earth, then, is a round body, or *sphere*, with a cold, hard surface.

Further, we know that the earth is being whirled round and round the sun, and though it takes us a whole year to get once round, we have to travel at the rate of nearly twenty miles a second to do so. But we are not the only body making this journey; altogether there are at least four or five hundred doing the same, and of the more important of these, known as the planets, we shall have more to say presently. Meantime you must think of the sun, and of the planets moving round it, as making up a group far removed from the other stars; and this group is known as the *Solar System*. Very likely the other stars have systems of planets too, but they are so far away that we cannot tell for certain whether they have or not. Still, there is much that we do know of them, and it is to be hoped that some day you will learn a little of the science of Astronomy that tells us about them. For the present we must fix our attention on the Solar System.

§ 6. We mentioned that the sun is made of much the same materials as our earth, only in a very different form, for everything on its surface is glowing with a heat so great that the hottest fire we know of would be quite cool by comparison. This makes it very difficult to give you any description of the sun, because we cannot realise all that is meant by such intense heat in so huge a mass—for it is nearly a million and a half times as large as the earth. This much, however, you can grasp: just as the earth has a covering or envelope round it, but quite distinct from it, which we call the atmosphere, so the body of the sun, as we see it when it sets, or through mist, has an outer covering of glowing vapours. And you will have some idea of what is meant when we speak of its intense heat, when you hear that among these vapours are iron gas and copper gas:

that is to say, iron, copper, and other metals, in a state of such heat that they remain not merely molten, but in the form of *gas*, just as water, when it boils, turns into the gas we call steam. This vapour covering is called the *chromosphere*, and from it enormous jets of flame and gleaming cloud shoot up, sometimes thousands of miles in height; while even beyond these again, lies the mysterious *corona*, only

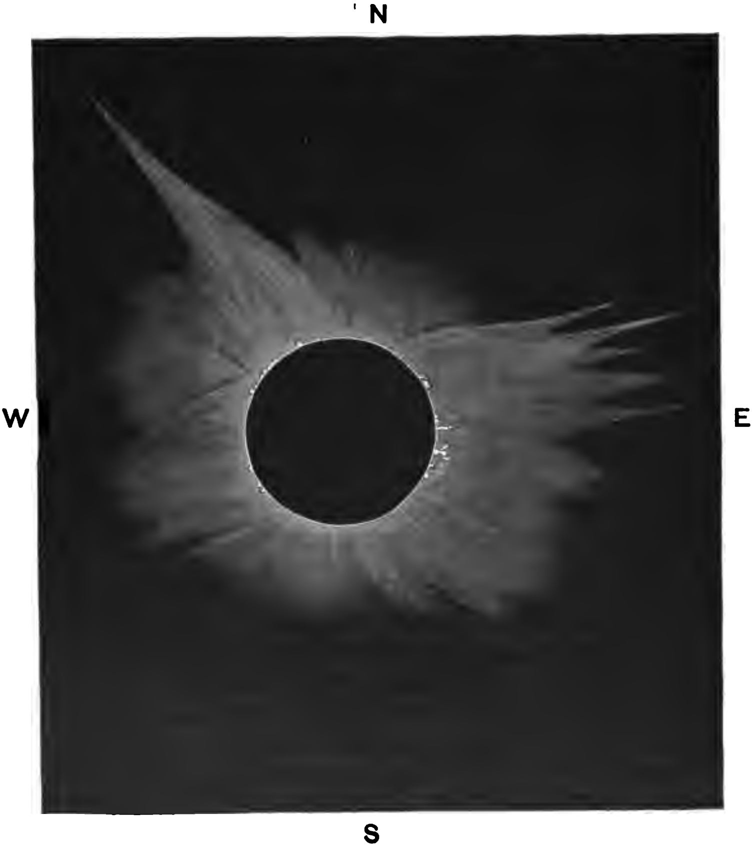


FIG. 1.—ECLIPSE OF THE SUN (August 9, 1896)

seen during an eclipse, and probably made up of still lighter gases, especially hydrogen, which give a fainter light. The photograph of an eclipse of the sun on the opposite page, will help you to realise the size and grandeur of the corona.

Beneath these two layers of the solar 'atmosphere,' the corona and the chromosphere, lies the actual disc, or *photosphere.* This is even more brilliant than the upper layers, and is made for the most part of a substance called carbon —the same that gives us the brilliant light in our electric lamps. It is not a solid mass, like the surface of the earth, but rather in the form of dense clouds. Immense currents of vapour from above sweep over and into it, and though these far exceed anything we know of heat here, they are often cool as compared with the awful heat of the photosphere, so that the places where they fall on it appear black by comparison. Such at least is thought to be the origin of what are known as *sun-spots,* some of which are as much as 150,000 miles across.

§ 7. In dealing with the other members of the Solar System, our first difficulty will be to keep some idea of proportion in our heads; that is, to realise the comparative sizes and distances of these various bodies. Let us see if we can do this in any better way than by a long string of figures. We will take a full-sized Association football to represent the sun; the planets, as you have them drawn here (fig. 2), will then be just the right size in proportion to it, so that you

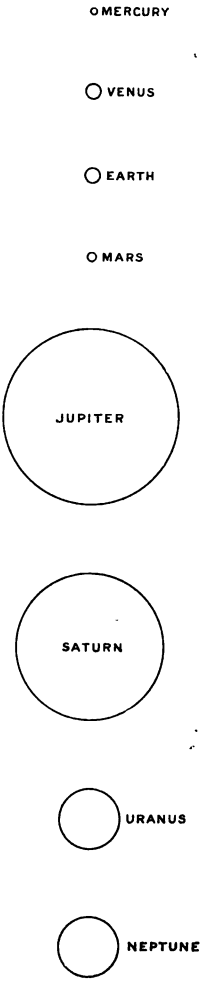


Fig. 2.—Relative Sizes of Planets

can see for yourselves how very much larger the sun is than the earth. Next as to their distances: well, the nearest, Mercury, you must put 31 feet away from the football, and the farthest, Neptune, will want 804 yards 2 feet, that is nearly half a mile!

All the other planets, like the earth, *revolve* round the sun, and in almost the same direction; but those that are further away go more slowly, and as they have further to go as well, it takes them much longer. So that Neptune takes over 160 of our years to get round, while Mercury does so in rather less than three months.

Among the planets, we know most about our nearest outer neighbour, Mars, which seems to be in some ways very like the earth on a smaller scale. It appears to have sea as well as land, and an atmosphere, and polar regions covered with ice; and astronomers have even made maps of, and given names to what appear to be continents and oceans, though it is not quite certain that they really are so. It shines in the sky with a very red light, probably due to the colour of the soil. But the planet most familiar to you, perhaps, is Venus, which is so often the 'evening star,' and sometimes shines so brightly as to cast a visible shadow. Mercury is too near the sun to be easily seen. Jupiter again looks very large and bright, though so much farther away, for he is 1,400 times as big as the earth. Saturn is chiefly remarkable for a very broad, thin belt round him, looking not unlike the rim of a soup plate. This belt consists of a number of rings, made up, as far as we can judge, of an indefinite number of tiny bodies circling together round the planet. Neither Uranus nor Neptune is visible without a telescope, and the former was long thought to be a star. The story of Neptune's discovery is one of the most wonderful in the whole history of astronomy.

You may perhaps wonder why it is that if the other planets are like the earth and do not give off light, they yet shine so brightly in the sky. The reason is that they shine owing to the sunlight reflected from them—that is to say, in their 'daylight.' Venus, for example, is often above the horizon without our seeing it, because the sun is shining on the opposite side, and the dark half is facing the earth.

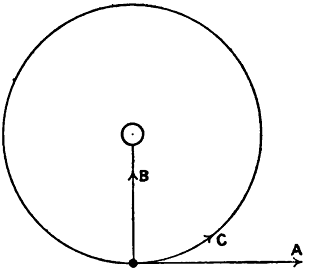
§ 8. We have said nothing yet of the moon, though it seems as if it ought to be next to the sun in importance, judged by its appearance in the sky. But though it looks as big as the sun, in reality it is only a fiftieth the size of the earth, and its apparent size is due to its being so very much nearer. It is, in fact, only a quarter of a million miles away, and much the nearest to us of all the bodies in space. The vast ridges and hollows on its surface can be seen quite plainly, and the shadows they make have long been familiar to us as the 'Man in the Moon.'

The moon revolves round the earth as the earth does round the sun, and is therefore what is known to astronomers as a *satellite,* a word which means 'companion.' Nor is the earth the only planet that boasts of a moon or satellite. Saturn, indeed, has eight of them, as well as the rings we spoke of just now. Jupiter comes next with five, and only the two smallest planets are without any at all. Our moon is, however, peculiar in one respect: it is far larger in proportion to its planet than any of the others, and we shall have more to say of it later.

§ 9. It will probably have occurred to some of you to wonder why these different spheres act in the way we have described, and this is not an easy question to answer; but as we go on we shall meet with certain facts which underlie all that we know of the universe, and as these facts are found always to be true, but cannot be explained, they are often called *laws of nature,* for they seem like rules that nature has to obey.

Thus we mentioned in speaking of the sun, that the materials of which it is made are the same, for the most part, as those which make up our earth, but that most of them are found in the form of gases. Now, this illustrates one of these great facts or 'laws' to which we shall often have to refer. It is found that *all substances expand when heated, and contract when cooled.* So when a substance is heated, and expands so much that it can no longer remain solid or liquid, it becomes a gas, which, as you know in the case of steam, takes up much more space than the same amount of material in a liquid form.

Well, then, the fact that the planets continue to revolve round the sun, and the satellites round their planets, illustrates another of these 'laws,' which is of great importance in helping us to understand some of the main facts we have to deal with in this part of our subject. It has been found that every mass attracts every other mass, but that the smaller is drawn towards the larger more than the larger one is towards the smaller; and the greater the difference is between them, the more one-sided the attraction becomes; so that, for instance, when a stone falls to the earth, to be strictly exact we ought to say that the two fall together, but the earth is so much larger than the stone that it can hardly be said to move at all. Again, the farther two bodies are apart, the less becomes their power of attracting one another. These are roughly the facts included in what is known as the *law of gravity.* It must also be noticed that any moving body will continue to move in the same direction (and at the same speed), unless some force stops it or turns it aside, and so from the moment the planets and satellites came into existence they would have moved away in a straight line—that is, in the direction in which they were moving at that moment—but this tendency is exactly balanced by the opposite one, that of attraction towards the larger mass, as expressed in the law of gravity, and these two forces acting together keep them moving always at about the same distance from that mass (fig. 3).



A represents direction of motion from rotation
B " " " " " attraction
C " actual direction of motion

FIG. 3.—THE EFFECT OF ATTRACTION

§ 10. But how did they come into existence? This is still more difficult to answer, and we can only hope now to get a very little way towards understanding how it may have come about. We spoke, at the beginning, of the stars, and saw that they were bodies like the sun, and thought it at least possible that many of them had systems of planets like our own. You know that on a clear frosty night an almost indefinite number of these stars can be seen, and there are even more which can only be seen with the aid of powerful telescopes, so that we cannot put any limit to their number and extent. But these are not the only objects revealed to us by our instruments. They show us also great luminous spaces—so vast, indeed, that the distance between the sun and its farthest planet would seem as nothing upon them—and these spaces, which astronomers call *nebulæ*, are filled with glowing gases spread out so fine that they are far lighter than any gas we know of on earth.

You must not suppose, for all this, that the nebulæ are quite shapeless, though it is difficult for us to realise such materials having a definite form. As a rule, they take the form of a spiral, rather like the firework known as a 'catherine wheel.' It is not quite clear why this is so, but we are fairly certain that there is movement going on in them; and in accordance with certain facts or laws that we know about bodies in motion, we are sure that this must in time make them take the shape more or less of a wheel, turning round on its centre or *axis* (fig. 4).

It is to these nebulæ we must look for an answer to our question; for we know enough of them to feel sure that they are really suns and worlds in the making, and that from one such nebula our solar system must once have grown. How exactly it was changed in the course of untold ages into a number of spheres moving in orderly arrangement, it would be useless to attempt to say, and, indeed, it is doubtful if the wisest of those who have studied the problem could fully explain it to you; still, it may be worth while to glance at some of the main principles at work in this transformation.

§ 11. That the gases in a nebula are so thinly spread out is due to its intense heat, but in the course of ages some of this heat will be lost; and as we saw that bodies when cooled contract, the nebula must shrink, till in time its gases become compressed into tiny liquid or solid particles, or, as we say, *condense*. Next, the law of gravity tells us that the nearer of these particles will be drawn to one another; and as more or less compact lumps are formed, the bigger will attract the smaller, and so in time we shall get a number of masses with the largest in the centre, to which all are more or less drawn. This central mass is very clearly seen in the photograph. We have already compared a nebula to a wheel turning

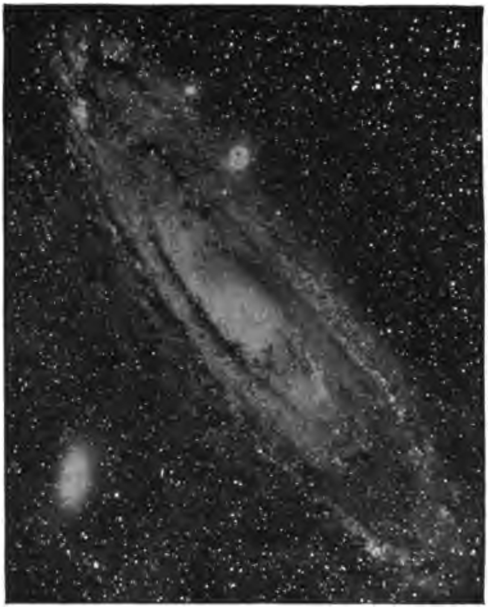


FIG. 4.—THE NEBULA IN ANDROMEDA
(*From a photograph taken at the Yerkes Observatory*)

round on its axle, and it is quite certain that the bodies formed as we suggested will continue the same movement: that is to say, the central sphere will rotate, and the others will revolve round it. Now, if you walk round a tree or a lamp-post, or in any way revolve in a circle, when you get half-way round you find yourself facing in the opposite direction to the one in which you started, and when you have got right round you are facing once more the same way. In other words, you have turned round or *rotated* at the same time that you were revolving round the tree. In the same way, when the bodies we spoke of revolve round the central mass they must also rotate; and for reasons that we cannot go into, the rate at which they rotate tends to get faster, so that in time they will rotate many times in the course of one revolution.

Lastly, you know that if you have a big piece of pudding and a small one on your plate, the small piece will get cool first; and this is equally true of everything else. So it is to be expected that the great central mass should remain incandescent long after the smaller ones revolving round it have become too cool, at least on the surface, to give off light. If you imagine the central mass as the sun and the others as its planets, you will have a rough idea of the way in which the solar system may have developed from a nebula. But you must not forget that this is scarcely more than a very probable guess at what has actually taken place, and that even if we could prove each step for certain, it would hardly bring us any nearer to understanding how the universe came into being, or what was the force that set it in motion, or why that force always seems to obey certain fixed laws.

Questions on Chapter I.

1. What is a star?
2. What is a satellite?
3. What is meant by the 'solar system'?

4. What is meant by a 'law of nature'? Give some examples.

5. Give the main facts contained in the 'law of gravity.'

6. What do you know of the sun?

7. Name the principal planets in the order of their distance from the sun. Which is the largest?

8. Give some account of Mars, Saturn, and the moon.

9. Give some account of a nebula.

CHAPTER II

MOVEMENTS OF THE EARTH AND MOON

§ 12. BEFORE inquiring more closely into the movements of the planets, and more especially of the earth, there is one point we must be quite clear about, namely, what is meant by an *angle*; for we shall find that on this depend most of the calculations we have to make, or at least to understand, in this part of our study.

You know that if two straight lines meet at any point in either of them, they make what is called an angle; and you know also that the size of the angle has nothing to do with the length of the lines which make it; so that of the two angles in fig. 5, the left-hand one is much the bigger, though the right-hand one is made by much longer lines. But you would probably find it more difficult to say how much bigger one was than the other—in other words, to *measure* them. To do this we must make the point at which they meet the centre, and the lines which make them, the spokes, or 'radii,' of a circle. Next, we divide the rim or 'circumference' of the circle into 360 equal parts, called *degrees*; then the distance between the radii which make the angle is measured by the number of degrees between the points where they touch the circumference. Thus, when we know that the part of the circle drawn in fig. 6 is divided into spaces of five degrees, we see at once that the angle made by the two radii is one of thirty degrees. A great deal can be learnt about the

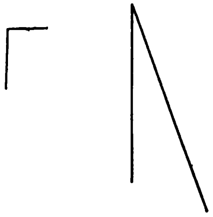


FIG. 5.—ANGLES

measurement of angles by looking at the dial of a clock or watch. First of all it will show you that the size of the circle does not make any difference to the angles, for that made by the minute and hour hands at any given time is the same on an eight-day clock and a lady's watch, if both are keeping time together. Now the circle or dial round which the hands move is divided into sixty divisions; that makes one for every six degrees, and every five of these divisions is marked with a number—generally in Roman figures—I., II., III., IIII., &c., each representing an hour, so that there are thirty degrees between each figure. Then if the smaller hand is at III or IX. and the larger at XII. they make an angle of ninety degrees, and this is called a *right angle*. But if one hand is at XII. and the other at VI. the two hands will be in a straight line, or an angle of 180 degrees.

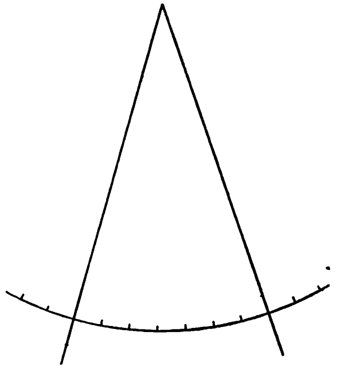


Fig. 6.—Measurement of Angles

If we made our circle large enough, we could divide each degree into smaller divisions, and if we made it larger still we could divide up each of these again; the divisions agreed upon are that of each degree into sixty parts, called minutes—not to be confused with the minute spaces in the dial of a clock; and of each of the sixty minutes into sixty parts called seconds. And just as, instead of always writing pounds, shillings, and pence, we put £. *s.* and *d.* after the number to show what it represents, so we write °, ′, ″, to represent degrees, minutes and seconds.

§ 13. Now as to the movements of the earth. First, we have seen that it rotates, just as a cart-wheel rotates on the axle, or rather we might compare it more correctly to a top, for the earth, like the top, has no axle, but spins round an imaginary line through its centre called the *axis*, and the two ends of this imaginary line are called the *poles*; and it takes, as you know, twenty-four hours to go once completely round. Secondly, the earth revolves round the sun in a plane: that is to say, if a line were drawn following the path taken by the earth, or, as it is called, its *orbit*, this orbit would form the edge of a flat disc—like a tea-tray without the rim. The imaginary disc is therefore called the *plane of the earth's orbit.* If you do not feel quite clear about the difference between a plane orbit and one not in a plane, just think of the difference between the rims of the wheels in a new bicycle, and the same rims after a collision with a stone wall!

Now nearly all we need to learn about the movements of the earth depends on one very simple fact, namely, that the line which we called its *axis is not perpendicular to the plane of its orbit.* You will better understand what is meant by this from the diagram below (fig. 7). The right-hand globe represents the earth with its axis at right angles to the plane of its orbit; the left-hand one represents it as it really is, that is at an angle of 66° 30′. This is known as the *inclination of the earth's axis.*

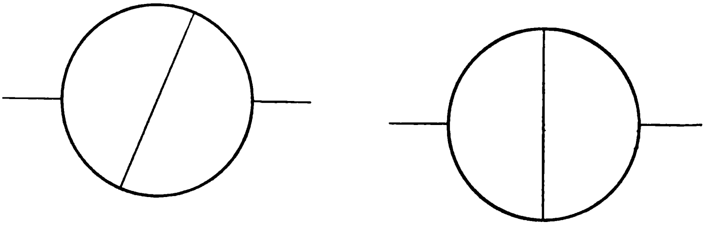


FIG. 7.—INCLINATION OF AXIS TO PLANE OF ORBIT

§ 14. First let us see what would happen if the axis were perpendicular. If the light falls on a globe from one direction only, it will light exactly one half of the globe and no more, and if the axis were at right angles to this direction, the line where the light half ended, and the dark half began, would make a circle passing though both the poles, as in fig. 8. Now our globe is turning round the opposite way to the hands of a watch (fig. 9), or, as we say, from west to east, so that any point on it moves round eastward till it comes into the lighted half—that is to say, into sight of the sun, which therefore seems to rise in the east, and to get more and more overhead till our point has reached the middle of the light half, or, as we say, 'mid-day'; and from that time the sun seems to get lower and lower down till we get into the dark half again, when it disappears altogether from sight, or 'sets.' And as the globe turns once round every twenty-four hours, each point on it would have an equal time in the light and in the dark, that is, twelve hours day and twelve hours night, except at the actual poles, where the sun would always be just in sight, or, as we should say, on the *horizon*. The first result, then, would be equal days and nights all over the globe.

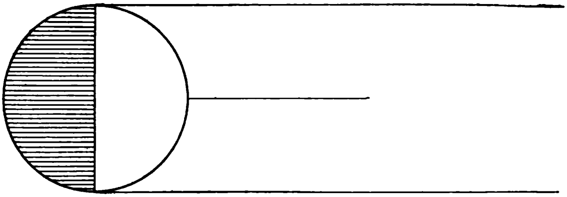


FIG. 8.—LINE OF SHADOW—AXIS PERPENDICULAR

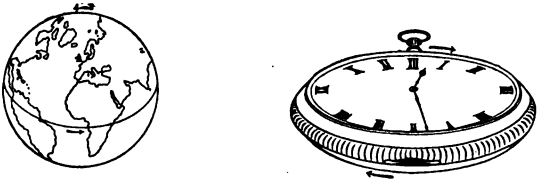


FIG. 9.—DIRECTION OF ROTATION

Secondly, this would be just the same wherever the earth was on its path round the sun, that is, all the year round; and so there would be no difference between what we call the seasons.

Thirdly, the line round the centre of the earth, that is to say, half-way between the two poles, called the *equator*, would always be the hottest part, because the sun would always be shining directly overhead on some point in it.

§ 15. What was said just now about the equator needs some explanation. You know, of course, that it is hotter in the middle of the day, when the sun is higher overhead, than it is in the early morning and the evening, but you have probably never thought why it is so. Well, light and heat are really waves which travel from whatever produces them, and strike the thing that is lighted or heated by them, so that we speak of the sun's rays 'striking' the earth. Now, if you imagine the upright lines in the figure below (fig. 10) as rays of heat or light, you will see that they all fall on the flat surface, A, which lies at right angles to them. But suppose we tilt our surface up at another angle, so that, for example, it is in the position of the dotted line B, you see at once that though the surface is the same, only half the rays strike it, and the more you tilt it up the fewer rays will fall on it; and this is just as true whether the upright lines represent one ray or a million. The equator, then, or that point of it where it is mid-day, is in the position of A, while the further north and south you go towards the poles, the more the surface becomes tilted at an angle with the sun's rays, and fewer and fewer of its rays will strike the same amount of surface, or area.

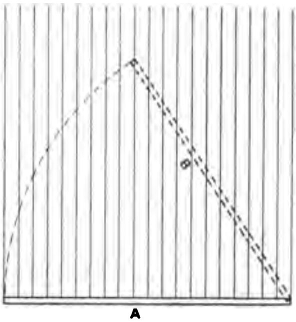


FIG. 10.—STRAIGHT AND SLANTING RAYS

You can now understand why it is hotter at mid-day than in the early morning or the evening, and also why it is hotter at the equator than it is near the poles.

§ 16. So far, we have been treating results of the earth's movements as if its axis were really perpendicular to the plane of its orbit. Now let us see what difference is made by the axis being at an angle of 66° 30′, as we drew it in the left-hand globe of fig. 7. As it is there, you will see that the circle dividing the light half from the dark half, which we will call the line of shadow, does not pass through the poles at all, but at a distance equal to 23½° from them, for we saw that the axis makes an angle of 66½° with the plane of the orbit, and as this is at right angles to the line of shadow, that is an angle of 90° (see § 11), the difference between the ends of the axis and the line of shadow must be 90° − 66½°, which is 23½° or 23° 30′.

Now, if you think of this globe as rotating on its axis, you will realise that any point within 23½° of the north pole will never get into the dark part at all, and, in the same way, any point within 23½° of the south pole never gets into the light half. So, if a circle is drawn at 23½° from each of the poles, we shall find that within the two circles the sun either does not set at all, or does not rise at all. The one round the north pole is called the *arctic circle* and the one round the south pole the *antarctic circle*, and as the earth is drawn here (fig. 11), the region within the arctic circle is always in light, and that within the antarctic circle in darkness.

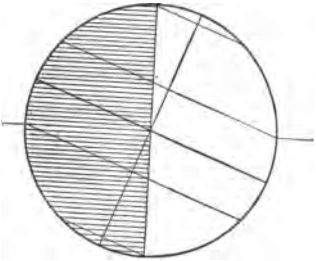


FIG. 11.—RESULT OF INCLINATION OF AXIS (SUMMER SOLSTICE)

§ 17. Again, the point where the sun's rays fall straight down, or vertically as it is called, is no longer on the equator, but 23½° nearer the north pole. So if we draw a line 23½° north of the equator, we shall get the line along which the sun is directly overhead at mid-day. This line is called the *tropic of Cancer*.

Lastly, you see that the line of shadow cuts the equator in the middle, and so if you were standing at a point on the equator you would be carried round in the light half and the dark half of the globe equally. But as you go farther north it is clear that you will be carried round more in the light half than in the dark half, that is to say the day will be longer than the night, till when you come to the arctic circle you will not come into the dark at all, as we saw before. On the other hand, the further south you go, the shorter will become the days, and the longer the nights till at the antarctic circle you will have no daylight at all.

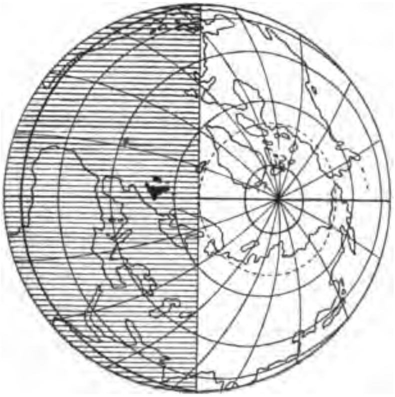


FIG. 12.—RESULT OF INCLINATION OF AXIS (POLAR VIEW)

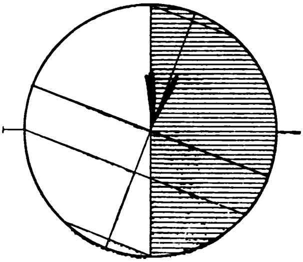


FIG. 13.—RESULT OF INCLINATION OF AXIS (WINTER SOLSTICE)

It may help you to realise this more clearly if you imagine yourself looking down on the earth from above, so to speak, that is from a point above where the line of shadow touches the arctic circle (fig. 12).

§ 18. So far, then, it is clear that it will be warmer in the northern half of the globe, or *hemisphere*, than in the southern hemisphere, and that the days will be longer. But will all this be the same throughout the year? Certainly not.

When the earth has travelled round to the other side of the sun, the north pole will be tilted away, and the south pole towards the sun (fig. 13). So that now the antarctic region will never be in the dark; the sun will be directly overhead at mid-day along a line 23½° south of the equator, called the *tropic of Capricorn*; the days will be longer as you go south, and shorter as you go north of the equator, and in the arctic region there will be no daylight. In a word, it is winter now in the northern hemisphere and summer in the southern; whereas in the position we first described it was summer in the northern and winter in the southern hemisphere.

Again, when the earth is just half-way between these extremes, neither of the poles will be pointing more towards the sun than the other, but both will be exactly on the line of shadow. What will happen now? Every part as it moves round will be equally in the light and the dark half, so that the days and nights will be equal all over the globe, except just at the poles, where the sun will remain exactly on the horizon. It will be directly overhead at the equator (see figs. 14 and 15).

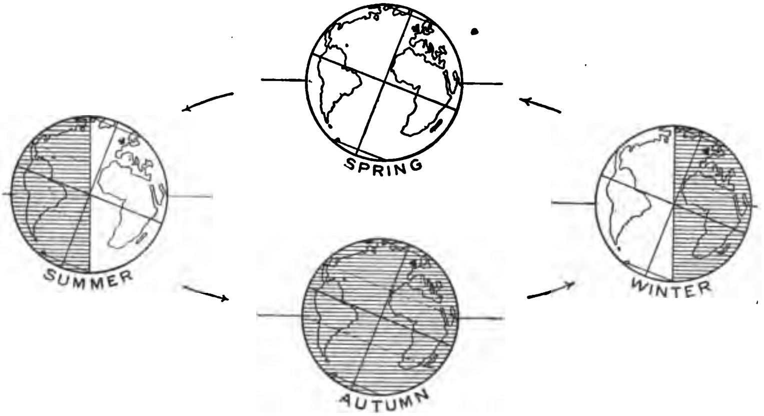


Fig. 14.—The Seasons

Here, then, in fig. 14, are the four positions put together, with our own island clearly marked in each case, so that you can see exactly what happens at different times of the year.

The left-hand globe is of course our summer, when the days are longest, and the sun highest over our heads. The next, following the arrow, is our autumn, when the days and nights are equal; the next, winter, with its short days and long nights; and the fourth, spring, when the days and nights are equal once more. So you see the seasons all depend on the inclination of the earth's axis. In the next figure (15) you have the same positions, only looked at from above.

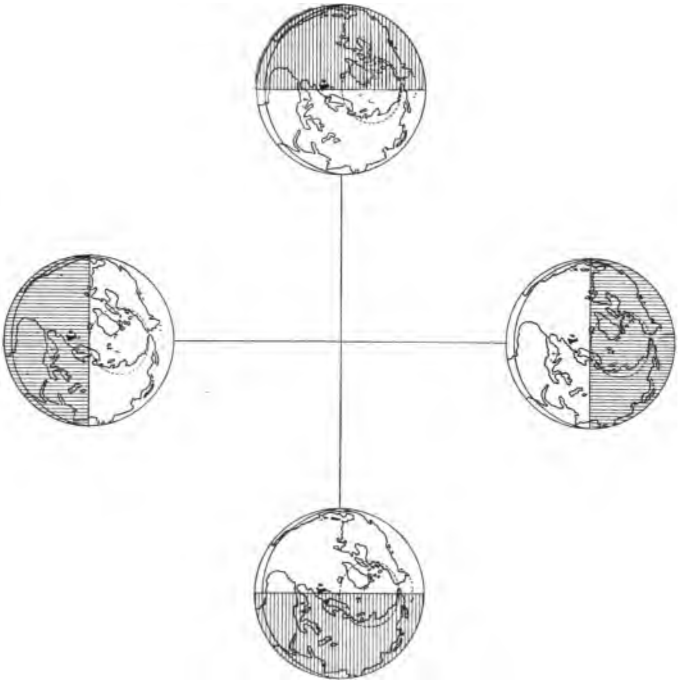


FIG. 15.—THE SEASONS (POLAR VIEW)

The moon's orbit makes an angle of about 5°, and it revolves round the earth in twenty-eight days. Like the planets it also rotates, and this it does in exactly the same time, and that is why we only see one side of it. But why do we usually see only a part of that side? The reason is that, like the planets, we only see it when it is lighted up by the sun; and

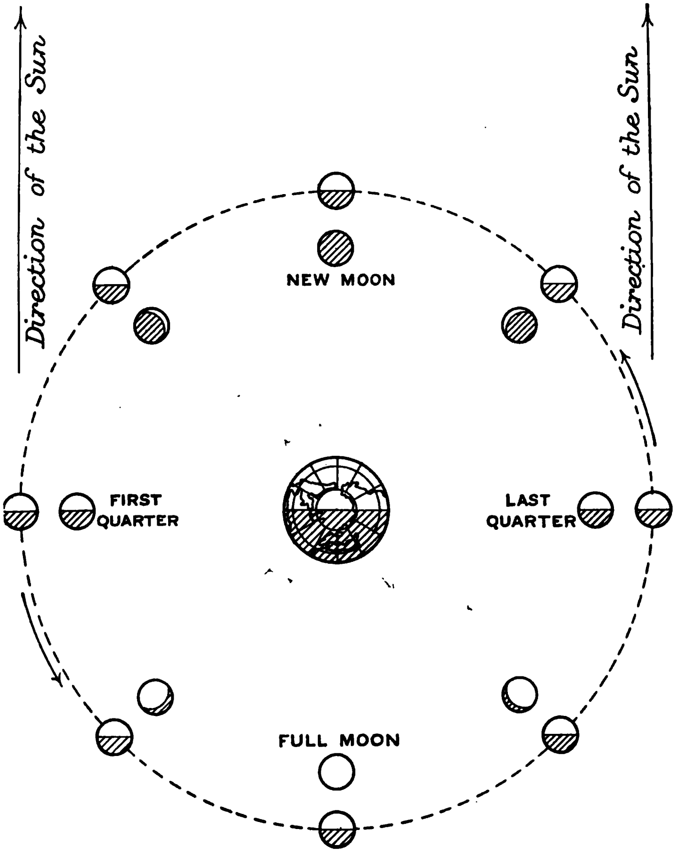


Fig. 16.—Phases of the Moon

so when both moon and sun are in the same direction we do not see it at all, or, as we say, 'there is no moon.' After fourteen days, when the moon is half-way round its orbit, we see the sun shining on the full half opposite to us, and we call it 'full moon.' In between these two periods we only see a part of it, as you will understand from the accompanying diagram of what are called the *phases of the moon* (fig. 16).

§ 19. You will now be able to see the importance of its plane of orbit making an angle with our own (fig. 17), instead of both orbits being in the same plane (fig. 18). This would mean, if you think of it, that every time the moon came round to the same side of the earth as the sun, it would pass exactly between us and the sun, and so hide the sun from us; and when it was at the opposite side to the sun, we should hide the sun's light from it. So that what is called an *eclipse of the sun*, and an *eclipse of the moon* would take place every month, at a fortnight's interval from each other. As it is, they only take place at intervals of about six months, and even these are not always complete eclipses, but only partial ones.

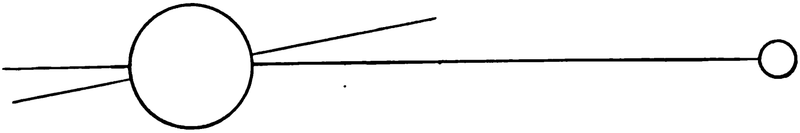


FIG. 17.—PLANE OF MOON'S ORBIT

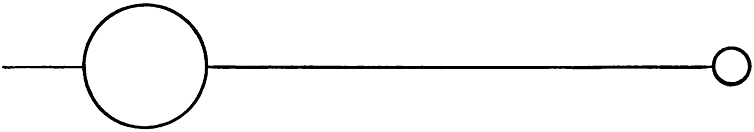


FIG. 18.—PLANE OF MOON'S ORBIT (IMAGINARY)

§ 20. A moment's thought will also show you why the moon rises nearly an hour later every day. Suppose yourself standing at the point A in fig. 19. The line drawn from A represents the horizon, so that if the moon is at the point B, where this line touches its orbit, it will just appear on the horizon. Now imagine yourself being carried round as the earth rotates; in twenty-four hours you will have again reached the point A, but will the moon be still just on the horizon? No; it has been travelling meantime along its orbit and gone one twenty-eighth of the distance round, so that it will now be at C instead of at B, and you will have to be carried round one twenty-eighth of a rotation of the earth more to the point D before the point C comes on to your horizon.

We said just now that you could only see the part of the moon that is lighted up by the sun. This is not quite true, for you may sometimes have noticed on a very clear night when there is a crescent moon that the rest of its disc is faintly visible. The history of this faint light is curious. It is the sun's light reflected from the earth on to the moon, and from the moon back on to the earth, or, as we might say, the 'earth-light' on the moon; which of course is much stronger than the 'moonlight' on the earth, because the latter is so much bigger.

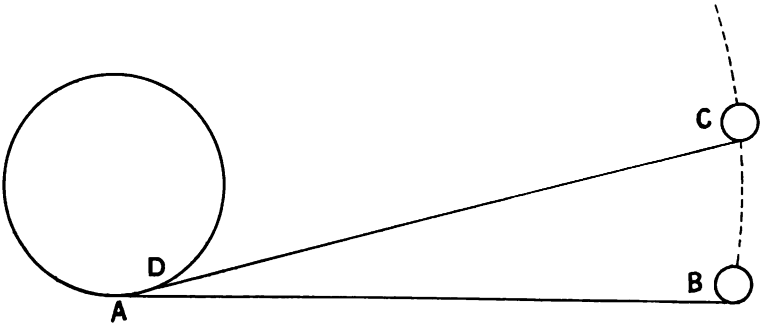


FIG. 19.—VARIATION IN TIME OF MOONRISE

§ 21. Up to now we have avoided, as far as possible, giving actual measurements and distances. But it will be as well for you at this stage to get hold of a few of the most important, as well as a few useful terms besides those we have already been obliged to use.

You may regard the earth's orbit as a circle with a radius of 93,000,000 miles, which therefore represents the distance between the centre of the earth and that of the sun. The times at which the poles point most towards the sun are called the summer and winter *solstices,* and these come on June 21 and December 21. The times in between, when both poles are pointing equally away from the sun, are called the spring and autumn *equinoxes* (equal night times), and these occur on March 20 and September 22.

As regards the measurements of the earth itself, you may take its *diameter,* that is any straight line passing through the centre from surface to surface, at 7,900 miles, and its *circumference,* that is any line drawn round the surface in such a way that if you cut the globe along this line it would be divided equally, at 25,000 miles.

How these measurements have been arrived at, as well as many of the facts you have learned about the distances and movements of the other bodies in the solar system, you will perhaps learn some day. If so, you will find there are many other important facts about the earth's movements which we have not been able to mention here, and also that the measurements given you are not exact, but only 'approximate' ones, that is, round numbers which you can more easily remember.

Questions on Chapter II.

1. Explain how angles are measured.
2. What is meant by (*a*) the plane of the earth's orbit; and (*b*) the inclination of its axis?
3. Give the main results of the latter (*b*).
4. Explain, with the help of a diagram, why it is hotter at the equator than at the poles.
5. State what you know of the movements of the moon.
6. What is an eclipse of the sun, and how is it caused?
7. Why does the moon 'rise' at a different time each day?
8. What are the solstices and equinoxes?
9. Give the approximate diameter and circumference of the earth.

CHAPTER III

LATITUDE AND LONGITUDE

§ 22. When you look at any ordinary globe or map, you see a number of lines drawn up and down, and others across it. We must now try to find out what these lines are, and what they tell us.

You remember that every circle was divided into 360°. Let us take one round the earth, passing through the two poles. Then the half-circle between one pole and the other will contain 180°, and, as we saw that the equator was half-way between the poles, it will cut our half-circle into two halves, so that from either pole to the equator there will be 90°. If, then, at the points marking off each degree, we draw a circle round the earth parallel to the equator, we shall know that every point on any one of these circles is at the same distance from the equator, or from the poles ; and that along that circle the length of day and night, and the changes of the seasons are the same. These circles are called *parallels of latitude*, and they are about sixty-nine miles apart for each degree, or sixty 'knots' (sea miles) as sailors reckon distance. On maps of smaller regions, such as our own island, these are all drawn in, but on those of larger regions, such as the great continents, it is more usual only to draw in one for every five or every ten degrees.

Next let us measure off 360° along the equator, and at each degree draw a half-circle to the two poles ; we shall then have divided the globe into the same number of parts as we did by the parallels of latitude, only in the opposite direction. But you will see at once that there are two important differences between the last set of divisions called *lines of longitude*, and the first set. One is that the lines of longitude are not parallel like those of latitude, but all meet at both the poles. The other difference is that all the lines of longitude are half-circles of the same size, while the parallels of latitude are circles which get smaller and smaller as they go from the equator to either pole. So the difference between one degree of latitude and another is always the same, or nearly so, while the difference between each degree of longitude gets less and less towards the poles.

§ 23. The principle on which these lines are numbered is as follows: Those of latitude start from the equator as 0, and are reckoned towards the poles (90). So that in giving the latitude of any place it is necessary to add the words 'north' or 'south' to the number to show towards which pole it is reckoned. If, then, we are told that a place is on latitude 15° north, we know that it is 15° north of the equator. Longitude might, of course, be reckoned equally well from any one of the lines, and different ones have been used at one time or another by different countries, but it has now been generally agreed to take the line passing through the observatory at Greenwich as 0, and reckon east and west from that. So if we are told that a place is on longitude 43° east, we know it to mean 43° east of the observatory of Greenwich.

You can now understand that one great advantage of these lines is that by them the exact position of any spot on the globe can be fixed. London Bridge, for example, is 51° 30′ 24″ north latitude, and 0° 5′ 10″ west longitude, so that we could mark its place on a globe which had nothing but the lines of latitude and longitude drawn on it. This is of special advantage to sailors, for you will find later that there are ways of finding out the latitude and longitude by observation, and so of knowing where you are in the open sea.

§ 24. If you think for a moment it will be obvious that it is mid-day at the same time everywhere on any given line of longitude, for that line will be midway between the lines of shadow. That is why they are often called *meridians*. It must, therefore, be midnight at the same moment along the opposite line of longitude 180° away. Now the earth takes twenty-four hours to turn completely round, that is to go through 360 degrees, so it will take $\frac{1}{360}$ of that time to go through 1°. A three hundred and sixtieth part of twenty-four hours is exactly four minutes, consequently for every degree westward of a given point, mid-day will be four minutes later, or for every degree eastward four minutes earlier. Suppose, for example, it is mid-day at Greenwich it will at that moment be midnight in the Fiji Islands, which are at longitude 180°; at St. Louis or New Orleans in America, which are on longitude 90° west, it will be six hours before mid-day, that is 6 A.M.; at Cape Breton Island, on longitude 60° west, four hours before mid-day, that is 8 A.M.; and so on. In the same way all places east of Greenwich will have had their mid-day already. At St. Petersburg and Alexandria, which are 30° east longitude, it will be two hours after mid-day or 2 P.M., and so on till we get back to the Fiji Islands, where it is midnight again.

There is in this connection an odd fact which is worth noticing. Suppose you start on a voyage round the world, going westward; for every degree you travel your mid-day will be four minutes later—in other words, you will have gained four minutes, When you reach the opposite side of the globe this will have amounted to twelve hours, and by the time you come home again you will have gone through another 180° and gained twelve hours more; that is a whole day. So that you will have had one less day than if you had stopped at home, though, of course, each will have been a few minutes longer to make up for it. If you had started eastward instead of westward, the exact opposite would have happened; your days would have been slightly shorter, and you would have gained one more by your journey.

§ 25. Now, of course, we cannot take up our position away from the earth, and watch it turning round with the results we have tried to explain; but it has already been mentioned that some at least of these can be found by observation. There is one that you can very easily make for yourselves. You know that at mid-day in any given place the sun is directly overhead at some point on the same longitude, which point is for the time being the exact centre of the light half of the globe. But north of this point—that is, anywhere on the northern part of the same line of longitude—anything standing upright will be pointing more towards the north and will therefore make a shadow pointing in the same direction. In the same way any upright object south of the central point will make a shadow pointing southward. Before mid-day the same object would cast a shadow towards the west, and after mid-day towards the east. This is the principle on which *sundials* were made before the invention of clocks and watches. So if we know the exact time, allowing of course for the distance east and west from Greenwich, if we are using Greenwich time (see § 23), we can easily find the direction of north and south, by simply planting a stick upright in the ground, and noticing the direction of the shadow at mid-day; and if we draw a line exactly at right angles to the shadow we shall know where east and west are also. Again, suppose we know already the direction of north and south, we have only to wait till the shadow of an upright object points to the north to find out when it is mid-day; and this is extremely important on board ship, as you will understand in a moment. Nearly every ship carries a watch or clock set by Greenwich time and made to go very accurately, called a chronometer; and now suppose when we have found on board our ship by the shadow that it is exactly mid-day, our chronometer says it is one o'clock. What will this tell us about our position? First, it shows that our mid-day is behind that of Greenwich, and therefore that we are west of Greenwich; secondly, as mid-day is four minutes later for one degree of latitude, and we are one hour or sixty minutes later, we must be 15° west of Greenwich, that is somewhere on the line 15° west longitude.

§ 26. At night in the northern hemisphere we can get our bearings—that is, the direction of north, south, &c., in another way. There is a group of stars, or constellation, known as King Charles's Wain, something like a cooking pan (fig. 20), which is itself part of a bigger constellation called the Great Bear. If you follow the line of the two stars in it, marked A and B in fig. 21, upwards, you will find a bright star which is almost exactly above the north pole,

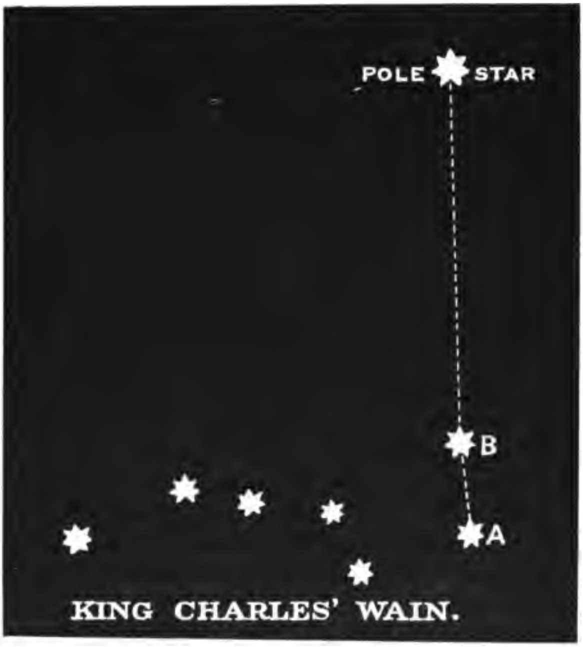


FIG. 20.—GREAT BEAR AND POLE STAR

and known as the *pole star.* That is to say, if the axis of the earth were produced far enough into space, it would nearly touch the pole star; and so when you face this star you know you are looking due north.

But the pole star has another important use. If you were standing at the north pole, it would clearly be straight over your head, and the further south you go, the lower it will be on the horizon, till at the equator it will be just out of sight. In other words, as you go southward from the pole, the angle of the pole star with the horizon—or surface of the earth—lessens from 90° to 0; or one degree for every degree of latitude. So, if we have an instrument capable of marking the angle between the star and the horizon accurately, we shall be able to tell our latitude. Such an instrument is called a 'sextant.'

§ 27. The method of finding our direction that is most familiar to us is, of course, the *compass*. But though it is the most familiar it is the most difficult to understand, and to do so would require some knowledge of what is called *magnetism*. In the meantime you must take it for granted that every magnet, whatever its nature is, has two poles, one called the positive pole, the other the negative pole, and that the positive pole of one magnet attracts the negative pole of another magnet. Now the earth is a great magnet, with its negative pole at the north, and therefore if another magnet is so placed that it can swing freely, its positive pole will turn towards the negative pole of the earth, that is to the north, and its negative pole towards the south. Unfortunately the magnetic poles of the earth are not quite at the true poles, nor are they always in the same place, so that in reckoning by the compass—which is nothing but a magnetic needle so balanced that it can swing round freely—allowance has to be made for this difference. At the present time the north magnetic pole is situated about 97° west longitude and 73° north latitude—that is, in the extreme north of Canada; but the exact direction in which the magnetic needle points in any given place is a very complicated matter. The angle which the needle makes with the line of longitude is called the *angle of declination*.

Questions on Chapter III.

1. What are lines of latitude and longitude? How are they drawn, and how numbered?

2. Rangoon stands at 96° east longitude and New York at 74° west longitude. What will be the time of day at each when it is mid-day at Greenwich?

3. How would you attempt to find your position in the open sea, given a chart (*i.e.* map of the ocean and surrounding land), a chronometer, and a sextant?

4. Explain the construction and use of the mariner's compass.

B. INORGANIC GEOGRAPHY

CHAPTER IV

FORMATION OF EARTH-LAYERS

§ 28. It is now time to consider what this earth of ours, which we have only spoken of so far as a 'ball,' or 'globe,' or 'sphere,' is made of; and to piece together a rough outline of its history.

There is one point about which you must be quite clear at the start, and try not to lose sight of. It is that when we speak of the 'solid earth,' we usually mean the crust or film of solid matter at its surface. We are so used to thinking of it as a vast solid mass, into which we dig mines and deep wells, and bore tunnels, that we are very apt to forget how thin this film is in proportion to the size of the globe. Remember that the diameter of the earth is 7,900 miles (§ 21), whereas the deepest mine is less than a mile down, that is, $\frac{1}{3950}$ of the way to the centre of the earth, or about the same proportion as the thickness of a good stout wall-paper has to the size of a rather small room.

One or two facts, however, we do know about the whole mass. In the first place its *density* is much greater than that of the average rocks which form the crust. That is to say, the whole globe weighs more than the same amount of matter, as it is found on the surface, would do; and as what are called metals, such as iron, gold, &c., are the heaviest kind of materials in the earth's crust, it is probable that they have a much larger place in its interior.

Secondly, it is always found that the deeper we go down from the surface, the hotter becomes the temperature. This rise in temperature is found to be, on the average, about one degree of our thermometer for every 60 feet. Now, at this rate, a depth of a few miles would give such a heat that metals like gold and iron would melt; and at one time it was believed that everything in the interior of the earth was in a molten state. We know now that this cannot be so, but it is very probable that they would all be molten were it not for the immense *pressure* caused by the weight of the mass above them, which keeps them solid and rigid.

§ 29. Everything we know of, on or in the earth—air, water, rocks, plants, animals—is made up almost entirely of mixtures and compounds of about thirty-six different materials, called *elements*. The following is a list of the principal ones in the order, roughly, of their amounts in the earth's crust:

Oxygen
Silicon
Aluminium
Iron
Calcium
Sodium
Potassium
Magnesium
Hydrogen
Carbon
Sulphur
Chlorine
Nitrogen

It is not expected that you should learn all these names by heart, but you must constantly refer to this list when any of the elements are mentioned, and in this way the names will soon become familiar to you. At first it may seem to you a queer collection; for oxygen, hydrogen and nitrogen are invisible gases. Iron and aluminium we know as hard metals, used for making various kinds of machines, while silicon is the chief ingredient in flint pebbles. But the compounds which they can form by their union in different proportions are almost infinite in number and diversity; and though it is certainly difficult to believe that such different things as our own bodies, a potato, and a railway time-table, are for the most part made of the same materials, yet it is so; and the composition of all matter has been traced back and back to these elements, by the wonderful science of *Chemistry*. It is therefore to this science that we must turn for an answer to the question, what our earth is made of.

In this connection you must also understand that the difference, which seems so great, between solids, liquids and gases—the three *forms of matter*—is only one of condition, first of temperature, then of pressure. We all know that water when it becomes very cold changes to ice, that is, it becomes solid; when it is very hot it changes to steam, that is, it becomes a gas. There are very few substances which change their form so readily, but it is equally true of all others: air can be turned into a liquid if only it is made cold enough, and we have seen that iron exists as a vapour in the sun (§ 6). As regards pressure we saw that this probably kept the interior of the globe in its solid form.

The combinations of these elements, which form the solid covering of the earth, are known as *minerals*.

§ 30. You would naturally expect that as soon as the outer crust of the earth became sufficiently cool and hard, the compound of oxygen and hydrogen, known as water, would take a liquid form and spread over its surface; just as the still lighter mixture of oxygen and nitrogen (the lightest of gases), which forms the air, spreads over the water. If so, what made the surface of the crust uneven, and so caused the water to collect in some places and leave others dry? Well, if you remember, we mentioned as one of the 'laws of nature' (§ 9) that matter contracts, that is gets smaller, as it gets cooler. So, as the earth got cooler it became smaller. Then, either the crust must squeeze together and become smaller too, or else it must wrinkle up so as to fit over the smaller bulk. To realise this you have only to think of an apple that has been kept till it has lost some of its moisture and shrunk, and of its skin, which cannot squeeze together, and so wrinkles up in order still to fit over the shrunken apple. This will give us the answer to our question. The crust of the earth wrinkled up, and consequently the water collected in the troughs or depressions. As soon as this happened, a series of very slow but continual changes began, which have completely altered its surface, and are still at work upon it.

§ 31. In order to get some idea of these changes, let us take the history of a drop of water coming down in a shower of rain. When it fell on the uneven crust, it would trickle along the surface from the higher to the lower parts. We must notice that this surface would not be quite smooth and hard; and to understand why, we must think once more of what we learnt in § 9—that heated bodies expand, and when cooled, contract. Now the surface of the original rock would be continually heated by the sun's rays, and cooled when not exposed to them at night, and still more in winter; and this would cause it alternately to expand and contract, and so become loosened from the mass beneath, and crumble, or as we say 'weather.' You can watch the same process for yourselves in buildings made from hewn stone, by comparing the 'face' of a new one with that of one that is older. Our drop would now meet other drops and form a rivulet, and the steeper the ground, the faster the rivulet would flow, carrying down with it the fine particles from the crumbled rock over which it had travelled, and as it was joined by other rivulets, and became a powerful stream, it would tear away larger fragments along its course, and so dig for itself a *bed*.

If you put some muddy water in a glass, and stir it round, the mud and water will remain mixed together; the mud is said to be in *suspension*. But if you let the mixture stand quite still, the mud will gradually sink to the bottom; it is then said to be *deposited* as *sediment*. In exactly the same way our stream, when its current is stopped by coming into the sea, or into a lake, will deposit the particles it holds in suspension. The heavier ones will fall first as *gravel*, the lighter as *sand*, and the finest will be carried on farthest, and finally be deposited as *mud*. So you see that one great result of rain falling on the earth's crust, was to wear away the higher part and carry it down to the lower, leaving it there in layers or beds of sediment. This process, which is still going on, is known as *denudation*.

§ 32. But this is by no means the only work that our drop of water has been helping to do. We learned that it was a compound of oxygen and hydrogen, but while it was in the air it picked up minute quantities of other things which are always present there, especially a gas largely composed of carbon. When it fell on to the earth's surface some of these substances united with various minerals in the rocks, which gave to the water others in their place, especially those known as *salts*. You cannot expect to understand why all this happened, till you have studied the science of chemistry, about which we spoke just now; but you know the difference between rain water, or as we sometimes call it '*soft water*,' and the water in wells or streams, which we call '*hard water*'; and from this you can realise that the earth must have made some change in the original drop. These salts are not in suspension like the particles of sand and mud we spoke of; they have become part of the water—'dissolved' in it; and so they are said to be held, not in suspension, but in *solution*. We must now see what happens to these salts.

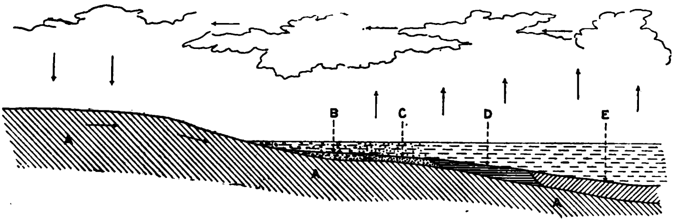
Let us take a flat piece of glass, and put on it a few drops of clean, hard water, and then let it stand in the sun. Before long the water will have 'dried up' as we say, and we must see what this exactly means. It means that the warm air has changed the liquid water into a vapour, and then absorbed this vapour; and the warmer the air is, the more quickly it will do so, as we know, because the warmer it is the more water vapour can it absorb and hold. But have the drops of water entirely disappeared? If you look carefully, you will find a thin coating of whitish matter left on the glass, and this is the salt which we saw was dissolved in it; for when water is changed into vapour, or *evaporated*, only the pure compound of oxygen and hydrogen is taken, and anything else that was in it has to remain behind. This is just what is always happening to the sea. The air draws up the water as vapour, leaving all the salts behind, and as more of these is constantly being poured in by rivers and streams, and remains there, the sea has become so full of salts that it is no longer the same as fresh hard water, but is what we call '*salt water*.'

Meanwhile our drop has become an invisible vapour; but we saw that the air can only hold this vapour in proportion to its own warmth. If then the air becomes cooler, the vapour will have to change back into water again, and will fall to the earth as rain. Then it will once more begin its task; taking from the air to give to the rocks, and taking from the rocks to give to the sea, then back to the air again, in a never-ending circle.

§ 33. The last section leads us on to consider another way in which solid matter is deposited in layers under the sea. If you were asked what animals live in the sea, you would probably answer at once: Fish; but in fact the fishes are a very small part of the life of the ocean. You have only to walk along the sea-shore to realise that there are vast quantities of animals of another kind, which live in the shells we find thrown up on to the beach; and besides these, there are myriads of tiny creatures, so small that you can hardly see them, floating on the surface of the sea. It is these last which have produced the most important results on the earth's crust. They, too, case themselves in shells made from some of the salts dissolved in the sea, mainly one of calcium, carbon, and oxygen. When they die they sink to the bottom, and before the water has had time to dissolve their minute shells, others have dropped and covered them over, and so a bed of what is called 'carbonate of lime' is formed at the bottom of the deeper water, just as the sand and mud were deposited nearer the shore. When you hear that some of these beds are hundreds, and even thousands, of feet thick you will realise what a vast time this process must in some cases have been going on.

The best way to sum up the results of this first step in geology will be to study carefully the illustration of them given in fig. 21. Of the water itself and the water vapour we shall have more to say later; the point to grasp now is its work in gradually forming different beds or layers of solid matter beneath the sea.

§ 34. If the process of denudation, just described, had gone on continuously, it is obvious that in time the dry land would all have been washed down to the level of the sea, which would thus have become to a large extent filled up. And in fact *all the land we know of has been at one time or another covered by water.* How then did it become dry land again? To answer this you must know something more about the wrinkling of the earth's crust. The main depressions, where the great oceans are, may have remained unaltered, but elsewhere there has been, and still is, a continual movement up and down of different parts. It is not difficult to prove this. On the east coast of England whole villages have disappeared under the sea, and on the south coast there are places, such as Porchester and Hythe, which we know to have been originally harbours, but are now quite cut off from the sea, showing that in one case the land has sunk, and in the other that it has risen; and this in a period of time which is quite insignificant compared with the millions of years during which the events we are dealing with have been going on. In the same way caves hollowed out by the waves and the remains of former sea-beaches are found in different parts of the world hundreds of feet above the present sea-level. Now each time the crust was raised, or *upheaved*, in any place above the sea, the old process of denudation would begin again, and so layer after layer has been formed under the water, then gradually risen or sunk so that a different deposit was formed over it, then perhaps risen till it became dry land again, only to be washed down again to form new beds. That is why we find them piled one on top of the other, sand on gravel, and chalk on clay; and as these beds are laid one above the other they have got the name of *strata*, a Latin word meaning things strewed or laid down.



A_Primeval rock. B_Gravel. C_Sand. D_Clay. E_Limestone.
The arrows represent the circulation of water

FIG. 21.—FORMATION OF SEDIMENTARY ROCK

§ 35. Meanwhile a change has gradually been taking place in the strata. If you remember the thickness of many of them, you will easily realise how great must be the weight on the lower ones. It is this weight, or pressure, that changes our sand, as we see it on the sea-shore, into *sandstone*, our carbonate of lime to *chalk* or *limestone*, and our gravel, when the spaces in between are filled up with mud or sand, to *conglomerate*. And this is not the only kind of pressure brought to bear on them. As the earth slowly contracts, the crust, as we saw, gets squeezed together wherever this is possible (§ 30), and so the strata are subjected to what is called *lateral pressure*—that is, one not from above, but from the sides—and are thus made still harder and more compact. Rocks formed in this way are often called *sedimentary rocks*, because they are made of sediment deposited by water, and they are said to be *stratified* because they lie in strata one above the other.

Questions on Chapter IV.

1. What do you know of the interior of the earth?
2. What is meant by an element? Name some of the commoner ones, and give examples of where they are found.
3. Describe how water causes denudation.
4. What is the difference between 'soft,' 'hard,' and 'salt' water?
5. Explain the expressions: mineral, stratified rock, suspension, evaporation, lateral pressure.
6. Give any evidence of changes in the level of different parts of the earth's crust.
7. Describe the formation of a stratum of limestone.

CHAPTER V

MOULDING OF THE EARTH'S CRUST

§ 36. BESIDES the gradual changes described in the last chapter, the earth's crust has at different times undergone sudden and violent changes from what is called *volcanic* action. Strange as it may seem, this appears also to be caused by the action of water. In the last chapter we spoke of it as coming to the surface of the earth in the form of rain, and travelling along the surface to the sea; but you must realise also that much finds its way beneath the surface as well. Thus, when you go into a cave or tunnel, you will almost always find water dripping through the top or trickling down the sides, and when a mine is sunk in the ground, water always collects in it, and has constantly to be pumped out. It is therefore most probable that in places, especially where the earth's crust has been wrinkled outwards, and loosened, water finds its way in large quantities to a depth where the heat of the earth is very great (§ 28).

It is also possible that in such places the wrinkling out of the crust, by lessening the pressure on the mass below (§ 28), may have turned the upper part of it into a more or less liquid form; in which case the water will mix with it. But in any case the water will of course be turned to steam—that is, it will take the form of a gas, and so expand very greatly. You know that the expansion of a very small quantity of water, when it is turned into steam, is powerful enough to move a very heavy railway train; and you know also that if the steam cannot find any way out, it will burst the boiler which holds it; in the same way, when a great quantity of steam has collected in the mass below, sooner or later the crust will do exactly as the boiler does—it will burst.

§ 37. Where a *volcano* is made, a hole is blown out of the crust, through which first of all the imprisoned steam and other gases escape, forming a huge cloud above it, then the molten mass, which, as we have seen, is also charged with steam, will be squeezed out by the pressure round it. This liquid rock, called *lava*, will flow out on all sides, and soon become cold and harden, while more keeps on pouring over the top of it. Meanwhile the steam mixed with the lava rises in bubbles through the hole or funnel, and as these bubbles burst they send up clouds of fine dust particles—the remains of their shattered films—into the air. Some of these particles are thrown to a great height, and carried immense distances by the wind; so that the crops over a part of Scotland were once completely destroyed by the volcanic dust from an eruption in Iceland. But as the top of the lava column in the funnel cools, these steam bubbles have to burst through the solid crust thus formed, and in doing so they will hurl upwards larger fragments, and even great blocks of solid lava. Though, as was said just now, some of these fragments and particles are carried great distances—for even huge blocks are sometimes hurled miles away—a great part falls back on to the volcano itself, and so forms the cup at the top, called the *crater*, while inside this a *cone* is usually found round the funnel itself. Fig. 22 shows you a *section* of a typical volcano—that is, a picture of what it would look like if it were cut straight down through the middle; but it might

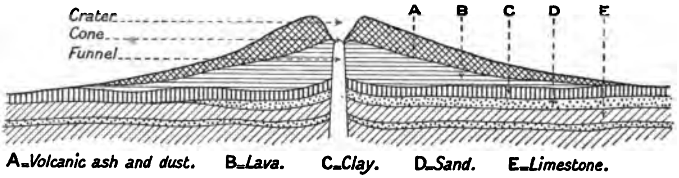


FIG. 22.—SECTION OF A VOLCANO

be very much changed by later *eruptions* as they are called, for these tend to occur again and again from the same volcano: often with an interval of centuries between each. During these intervals it is spoken of as *dormant*.

§ 38. But this is not the only form of volcanic action. Instead of a hole in the crust a long crack or *fissure* may be made, and in fact such fissures are often found round a volcano proper. If this happens, the lava will naturally flow into the crack as into a mould, forming what is called a *volcanic dyke*. Sometimes, again, a bed of rock will be lifted bodily up, and the stream of lava be pushed in between it and the stratum below.

Another serious disturbance of the earth's crust must probably be put down to causes of the same kind as we have been describing, or at least to some sudden change in the pressure on the interior mass, taking the form of *earthquakes*, or as they might be called 'earth-waves'—that is, a wave-like movement of the crust, often causing quite as much damage as a volcano.

Now you might think, as volcanic eruptions are not very common, and even volcanoes at all are rare in Europe, that they have not had a very important part in making the land; but you must remember that those volcanoes which exist now are only a very small fraction of all those that have existed. Many of the former ones can still be recognised, as, for instance, in the Auvergne district of France, and these are called *extinct volcanoes*; but by far the greater number have been so completely 'denuded' that their very existence is forgotten, and sometimes they can only be recognised by a 'boss' of volcanic rock, the remains of the lava in the original funnel. More commonly sheets or layers of volcanic rock remain, often covered in turn by other strata, or else scored and cut through by water into various forms. The greater part of Scotland and much of Wales are covered with such rocks, and there are traces of hundreds of volcanoes in England as well. We must therefore find out something about these rocks.

§ 39. The matter which has forced its way up from the interior of the earth is generally called *igneous*, as opposed to sedimentary rock. Of these *basalt* and *diorite* represent the outflow of lava in sheets or dykes. They are smooth and very hard, sometimes not unlike glass, while the dust and ash, which we described in § 37, form beds of what is called *tuff*. But the great characteristic of all igneous rocks which have been allowed to cool slowly, instead of being suddenly exposed at the surface, is that the minerals of which they are made *crystallise*. The study of this process is an interesting branch of the science of Geology; and from it you will learn that different minerals form themselves naturally into crystals, each of its own peculiar shape; and that if these are broken, they will as a rule only break into smaller crystals still of the same shape. A few typical forms of rock crystal are given you above (fig. 23), and you can learn much by noticing the different specimens in any museum. Some are transparent like glass, others are opaque, and in many so-called *crystalline rocks* they are bedded in a glassy non-crystalline mass. The commonest form of crystalline rock is *granite*, and the commonest mineral, which enters largely into the composition of granite as of other rocks, is a compound of oxygen and silicon, usually in crystal form, known as *quartz*.

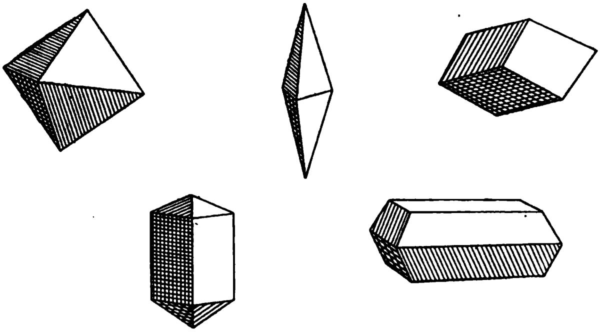


FIG. 23.—FORMS OF ROCK CRYSTALS

Lastly, to complete our account of the commonest forms of rock, we must mention the effect of these igneous masses on the older sedimentary rocks. Where they met, the latter have often been molten or 'fused' by the intense heat, so that their minerals have separated and reformed again, very often as crystals, either closely packed into a solid mass as in granite, or in uneven layers of what is called *schist*. The latter can be recognised by the fact that the layers of crystals break off easily in flakes. It is this same process of fusion which changes limestone into *marble*.

§ 40. We have now learnt something about what the earth's crust is made of, and how it came to be built up. Next we must consider how it got its present irregular surface, with its mountain peaks and precipices, its deep valleys and chasms.

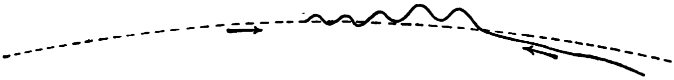


FIG. 24.—MOVEMENTS OF EARTH'S CRUST

In explaining the origin of sedimentary rocks, we only described what might be called a 'sagging' of the crust, such as we notice in the leather cover of a football when some of the air in the bladder has been taken out. Now at the edge of one of these sags or depressions there would be a decided weakening of the crust, for you know that it always weakens a solid thing to bend it, so that if you want to break a piece of tin or a twig you bend it first one way, then the other. Then, as the mass below contracted still further, the comparatively even parts of the crust would, by the lateral pressure we spoke of in § 35, push the weakened part from both sides, and thrust it up into a regular fold or wrinkle, or more probably into several of these folds or *plications*, as they are called, such as are shown in fig. 24. Let us see what the result would be.

First of all, the pressure immediately under the arch of the fold will be removed, and the interior mass will become molten and rise into it, with the same results as those we spoke of in connection with volcanoes. Then the outer strata would break, or at least crack, under the strain, just as a slice of bread does if you bend it too far. Then rain and frost and wind would combine to loosen the cracked arch still more, and in time it would fall, exposing the upright edges of all the strata. Of these the softer ones would be eaten away first by the same process of denudation, leaving the harder ones standing up for a time as peaks and crags (fig. 25). So you see that the lofty mountains found in the Alps, or even the Himalayas, are only the wrecks of vast continuous ridges, which are still being worn away; and though we speak of them sometimes as the 'everlasting hills,' and of things being 'old as the hills,' they are not in reality as old as much of the plains beneath them, and like all things on our earth undergo slow but resistless change.

§ 41. You will now understand why it is that we so often see stratified rocks with their different strata not lying flat or horizontal, as they were originally laid, but tilted up at all possible angles, and sometimes even folded over one another; and you will be able to read something of the marvellous story told by such rocks.

But you must not suppose that all the hills or even mountains have necessarily been formed in this way; though what was said in the last section will account for the great *mountain chains* of the globe. Thus many of the granite mountains of Scotland are only the remains of volcanic bosses and dykes which, being of harder material than the surrounding strata, have been left standing after these had worn away. Or, again, a volcanic sheet has in places protected the softer strata beneath from denudation, and so left a plateau which, though it has worn away more slowly than the surrounding rocks, is yet seamed and furrowed into hills and valleys. In short, the continual action of water (of which we shall say more later) even on one level bed of rock, and still more where strata of different hardness meet, is quite sufficient to cause great differences of height, and

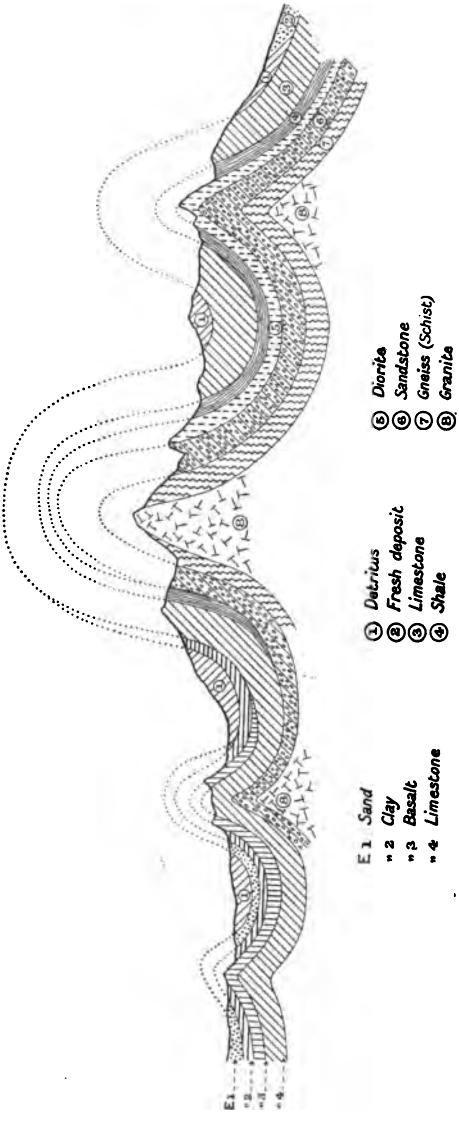


FIG. 25.—EFFECTS OF MOVEMENT ON STRATA

(*After Professor James Geikie.*)

endless diversity of landscape. We shall therefore be prepared to find ranges and groups of hills in all parts of the globe, and to remember that even when we speak of a plain, we do not necessarily mean that it is quite flat, but only so as compared with mountainous regions. At the same time it will be useful to remember also that we may expect to find the great mountain chains lying on the edge of the great depressions, that is to say of the great oceans. You can see this for yourselves by looking at a map of the globe, and noticing the position of the great continuous ridge running down both the American continents, the main ridge of Australia, and the chief ranges of Africa; though in the great Eurasian continent it is not at first sight so obvious.

§ 42. We have now sketched out very roughly the chief processes which have been at work to make the solid portion of the globe as we know it now. You will hardly need to be told that all these vast changes must have taken so long a time that it is impossible for us to realise it. Many of the events which we have spoken of as mere incidents, such as the complete wearing away of a volcano, or the formation of a bed of limestone, must have taken thousands of years, and the whole story of geology must therefore cover many millions.

But before we leave this subject, there is one very great fact connected with it which you must try to grasp. In these rocks, formed, as we have seen, through untold ages, are still to be found traces of the earlier forms of life on the earth: here the impress of a leaf, there a sea-shell, elsewhere the bones of some fish or reptile, or of some great monster unlike any animal existing now. And patiently, step by step, men have pieced together from these *fossil remains* the history of the earliest inhabitants of our planet. So you must learn to look on the rocks as nature's history books: books which can tell us true stories more wonderful than any imaginary ones, if only we can read them.

They tell us that the mysterious thing called *life* began in a humble, insignificant form, such as the little creatures we spoke of on the surface of the ocean; that these humble forms of life gradually acquired new shapes and new organs, each better fitting its possessor to live in that part of the sea where it found itself; how only after long ages of development some began to take to the land as huge reptiles, and new forms or *species* continually arose suiting themselves to new conditions; and how some of those disappeared, while others survived and developed fresh powers of body and brain, till finally the species we know as *man* appeared and gradually outstripped his rivals in the fight for the lordship of creation. Thus the most widely different forms of living things have been gradually 'evolved' from those that lived before them; and the steps by which this came about form the story of what is known as *evolution.*

Questions on Chapter V.

1. Describe the eruption of a volcano.
2. What are igneous rocks? Mention any peculiarity of them.
3. Give reasons for the position of the chief mountain ranges.
4. Describe the origin of some of the lesser groups of hills.
5. What are basalt; volcanic dykes; marble; schist; fossils?
6. What do we learn from geology about the history of 'life'?

NOTE.—Every effort should be made to familiarise the learner with the commoner kinds of rock, both sedimentary and igneous, and to encourage the collection of typical specimens.

It need hardly be added that the outline here given may with advantage be supplemented and illustrated wherever possible by reference to local features.

CHAPTER VI

THE ATMOSPHERE

§ 43. LET us now turn our attention to the outer wrapping of the earth, that is the atmosphere. We have seen that it is a mixture of two elements, oxygen and nitrogen, in gaseous form (§ 30). Though the amount of nitrogen in this mixture is nearly five times that of oxygen, the latter plays far the more important part in the work of the air. It is this which unites with the carbon in coal or wood to make what we call a 'fire,' and with the carbon in our lungs when we breathe in, making a sort of fire inside our bodies to keep them warm; and, finally, it is the oxygen which unites with the poisonous gases produced by decaying or putrid matter, and so makes them harmless.

But though this mixture is what is strictly called *air*, the *atmosphere* contains many other things as well which we could not possibly do without. These we shall consider in three groups. First, other gases; second, solid matter; third, water vapour.

Of the other gases we have already mentioned that one, made of oxygen and carbon (§ 32), is largely absorbed by rain and brought back to the earth, where some of it unites with the rocks, while a still more important use of it will appear later. This gas, known as *carbon dioxide*, is produced whenever anything is burned, and we also produce it when we breathe out; and much is constantly finding its way out from the interior of the earth. Ordinarily, there are only about three parts of it to every 10,000 parts of air, but naturally, where many people are breathing close together, or where much burning is going on, as, for instance, from a number of gas jets, the proportion is much greater, and makes the air poisonous for us to breathe, as it often is in a concert room or a theatre. There is also a gas consisting like air of oxygen and nitrogen, but with a much larger proportion of oxygen, called *ozone*. The amount of it varies in different places, and as it does the same work as air but with more power—for we saw just now that oxygen is the working part of the air—it has much to do with making some places more healthy than others, and is most abundant on or near the sea, and that is why the seaside or a sea voyage often does people so much good. Lastly, there are minute quantities of many other gases to be found in the atmosphere, of which the most important are *nitric acid* and *ammonia*, both compounds containing nitrogen and hydrogen, and sulphuric acid derived from sulphur. These, like the carbon dioxide, are washed down by the rain on to the soil, where, as we shall find, they are of great use.

§ 44. Next as to solid matter. You must all have seen the sunlight at some time or another coming through a chink into a dark room. It makes what we call a beam of light, in which we see thousands of dancing specks, and these specks or motes are present all through the atmosphere, though, as a rule, we only see them when they are lighted up against a dark background. Where do they come from? There are many sources; some are caused by solid things rubbing together. When we say, for instance, that a coat is worn 'threadbare,' or the soles of our boots worn 'through,' we mean that constant rubbing against the desk or the pavement has turned the nap and the leather to dust. If the air is quite still this dust will gradually settle on any surface, such as our book-shelves, but in the open, where the air is always moving, it will remain for the most part suspended. We have seen that rocks can wear to dust as well as coats and boots, especially when they take the form of a road! But in addition to this dust produced by denudation, which is chiefly found near the surface of the earth, there is another kind of quite different origin.

§ 45. There are innumerable bodies travelling through space at terrific speeds, and when one of these strikes against the atmosphere, it becomes so hot that it dissolves into vapour, and this vapour again condenses into solid form as dust. These are the *meteors* we often see at night and speak of as 'falling stars,' and we only see them after they have become glowing hot from striking against the upper air, before the denser air below has had time to turn them to vapour. Besides this dust, we have seen that some of the same nature is shot out from volcanoes (§ 37). These two sources give rise to the solid particles found in the upper air, for the dust caused by friction and denudation was, we saw, chiefly to be found lower down.

We shall not realise the full importance of these dust particles in the atmosphere till we have learned more about the last addition to it—water vapour; but one great result can be considered here. Let us return to our beam of sunlight in the dark room. We said that we saw the motes shining in it. Really it was *only* the motes that we saw, and if they had not been there the light would have left no trace on the air at all, for waves of light and heat pass through air without having any effect on it. So, if there were no dust in the atmosphere, the sun would appear as a dazzling ball in the midst of a black sky, and everything which did not directly catch its rays would be black too! As it is, the light-waves strike the dust particles and are reflected by them in all directions, so that the light is spread or *diffused* through the whole sky. At the same time the rays of the sun warm these particles, and the heat *radiates* from them and warms the air.

§ 46. The existence of water vapour in the atmosphere has already been touched on in § 32, to explain how the water came back from the sea on to the land, and so completed its 'circulation'; and we saw that the amount of it contained in the air depended on temperature. There are two facts to be learnt about this vapour before we can understand the forms it takes and the work it does.

We learnt in § 29 that the change of gases into liquids, and of liquids into solids, called *condensation*, depended mainly on their temperature. Now, when a lump of ice is melted in a pan over the fire, some of the heat of the fire has passed into the ice, and turned it to water. If it is again turned into ice, it will have to part with exactly that amount of heat which has been meanwhile, as it is called, *latent*, that is 'lying hid,' in the water. In the same way, if you boil the water and turn it to steam, more heat will have passed into the steam, and if the steam is again condensed to water, this amount of latent heat will be released, and pass into the surrounding air. Therefore, *whenever water vapour is condensed, the temperature of the air is raised.*

The second fact is partly a result of the first. If you are sitting in a warm room on a cold night, and open a window, you can feel the cold air, but no change is visible in the atmosphere of the room. Some of its water vapour probably was condensed, but the warmth thereby released, checked the condensation of the rest, or at least caused it to take place very gradually. Suppose now, instead of opening a window, you had brought in a glass of water having the same temperature as the air outside the room, you know that it would at once have become misty. In other words the vapour would have condensed on it, and would go on collecting there till it trickled down the sides in big drops. It is not difficult to see what has made the difference. The latent heat released by the first condensing could not warm the tumbler as it did the air, and so prevent further condensation. This at least will partly account for the undoubted fact that *water vapour condenses* more readily, that is *at a higher temperature, if it comes in contact with a solid body.*

§ 47. One common form in which the water vapour in the atmosphere condenses arises on the same principle as the mist on our glass of water. When the earth becomes cooler at night, the vapour condenses especially on those small objects which expose the largest surface, and so part with their heat most readily, such as blades of grass, leaves and twigs; and this condensed vapour forms into drops of what we call *dew*; and when the night is very cold this dew often freezes into solid crystals forming *hoar-frost.* But the chief condensation of vapour takes place round the solid particles we spoke of in § 45. When, for example, the moist air in a great city which lies on a river, such as London, becomes suddenly cooler, the vapour condenses round the specks of smoke and dust we described, forming a thick *fog.* Something of the same kind may often be seen over the sea, or on marshy ground, or pools, but it is not so thick because there are fewer particles of solid matter than in the atmosphere above a town.

Clouds are formed in the same way. When the water vapour, which we shall find makes the air lighter, rises from the surface of the earth by evaporation, it passes into cooler regions of the atmosphere, and begins to condense on the dust particles. The height at which the clouds begin to form will depend on the distance to which the atmosphere is kept warm by the earth's radiation of heat; and their thickness on the supply of water vapour. Their importance lies in forming as it were a blanket over the earth, which during the day absorbs much of the sun's heat and so makes the earth cooler, whereas at night it prevents the earth's heat being radiated outwards and so keeps it warm. That is why there is less dew on a cloudy night, and very rarely a sharp frost. On the other hand, in regions such as Arabia or the Sahara, where the atmosphere is so dry that clouds are seldom formed, the nights are often intensely cold, and the days intolerably hot.

§ 48. If a cloud is still further condensed, the minute drops come together and form bigger ones, which are too heavy to remain suspended in the air, and fall to the earth as rain. This further condensation may happen from one of several causes. The cloud may be cooled by a cold wind, or it may become 'saturated' with water vapour, that is so full that it can hold no more, and so as more comes up it displaces some that was there already; or again the cloud may be driven by the wind against high ground, perhaps a range of hills or mountains, in which case the cloud is forced upward into colder air; that is why, as a rule, mountainous regions are more rainy than low-lying ones. Lastly, they may be condensed by electricity, as we see in the case of a thunderstorm, which is nearly always accompanied by heavy rain. We have spoken of rain before, and shall often have to do so again, so we will only mention here its effect on the atmosphere. You know the expression 'clear shining after rain,' and you have probably noticed that you can see things much farther off on a bright day after a heavy rain, than you can when there has been a long spell of fine weather. This is because the rain has washed down immense numbers of the dust particles, which we saw were thickest near the surface, and so 'cleaned' the atmosphere. We have seen, too, that it picks up on its way down some of the gases we spoke of in § 43, which are badly needed by the soil.

§ 49. But rain is not the only form in which the condensed vapour finds its way down to the earth. Sometimes the drops are frozen on their way down into *hail*, but more often, when the temperature of the lower air is below the freezing point of water, the contents of the cloud freeze into minute crystals, such as we saw made the hoar-frost. In fact, most probably a great deal of what falls to the earth as rain was to begin with frozen in this way as *snow*, and only melted when it came into the lower and warmer parts of the atmosphere. You already know something about crystals, and have learned that minerals when they change from liquid to solid form usually do so in one of the many crystal forms. Now, water when it becomes

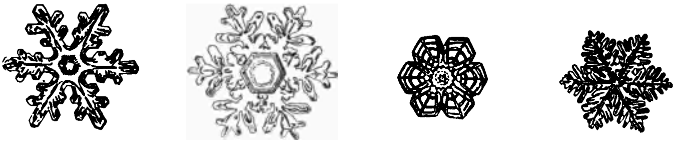


Fig. 26.—Snow Crystals

solid, whether as hoar-frost, or ice, or snow, always takes the same crystal shape. In snow-flakes these arrange themselves into wonderful patterns, which all have one feature in common, namely, that they are six-rayed stars (fig. 26).

§ 50. You will perhaps wonder how far above the earth this atmosphere stretches. This we cannot tell exactly, but it may perhaps extend as much as a hundred miles upwards. The important thing to remember is, that the nearer it gets to the earth the denser it becomes, and even at the height of many mountain peaks the lessening of the density is very marked indeed. This is only natural, if you think for a moment that the lower it is the more air there is pressing down on the top of it, and therefore the more it gets packed together. It is true, we are so accustomed to think of air as much lighter than any solid or liquid forms of matter, that we are apt to forget sometimes that it has any weight at all. But think, for a moment, of an ordinary pump. There is some water in a well and you want to draw it up into the spout of the pump through a pipe. What do you do? You take some of the air out of the pipe by an arrangement called a valve and piston, which is worked by the pump handle, and the weight of the air on the water in the well forces the water up into the pipe where the weight has been to a large extent removed. It is the same thing, on a small scale, when you suck the lemonade out of a glass with a straw; by breathing in, you draw the air out of the straw, and the pressure of the air on the liquid in the glass forces it up into your mouth. It has been found by careful experiment that the weight of the atmosphere is sufficient to cause an average pressure at sea-level of about 14½ lbs. to every square inch of surface; so that our bodies have a pressure on them of about twelve tons, for 'pressure' differs from 'weight' in being the same in all directions, and there is the same pressure beneath our feet upwards as there is on our heads downwards. The reason why we do not feel any of this tremendous pressure is, that the air inside us causes the same pressure *outwards*.

§ 51. We spoke just now of an *average* pressure, for the actual amount is constantly varying, from two causes. First, you know that bodies when heated expand; if then the air is heated it will expand, that is take up more space; and if a given weight of air takes up more space, it follows that there will be less weight of air in the original space. Secondly, it has been found that water vapour is lighter than air, so that the more water vapour there is mixed with the atmosphere, the lighter that atmosphere will be. These two facts may be put into a short form which you can easily remember: *Warm air is lighter than cold air, and moist air is lighter than dry air of the same temperature.* And it is important to remember it, for on this constant change of weight, and therefore of pressure, in different parts of the atmosphere depend its movements, which we call winds.

§ 52. The instrument with which we can mark exactly the changes in the pressure of the atmosphere is called the *barometer*, and the principle on which it is made is very simple. A glass tube, nearly a yard long and closed at one end, is filled with a liquid metal called mercury, then turned up with the closed end to the top, and the open end resting in a cup. Will it all pour out into the cup? No; very soon the pressure of the atmosphere on the mercury in the cup will just balance the weight of the column of mercury in the tube (which has no weight of atmosphere above it), and then the mercury will cease to flow out. But if the pressure on the outside should become less, it will begin to flow out again; if the pressure is increased, some will be driven back into the tube to restore the balance. Now, the average height of the column of mercury which exactly balances the pressure of the air is rather less than thirty inches, and it may rise or fall more than an inch above or below this point even at sea-level.

§ 53. The same metal is used in making the *thermometer*, by which the warmth of the air is measured; but in this, the glass tube is closed at both ends and made very narrow indeed, with a bulb at one end, so that when the mercury

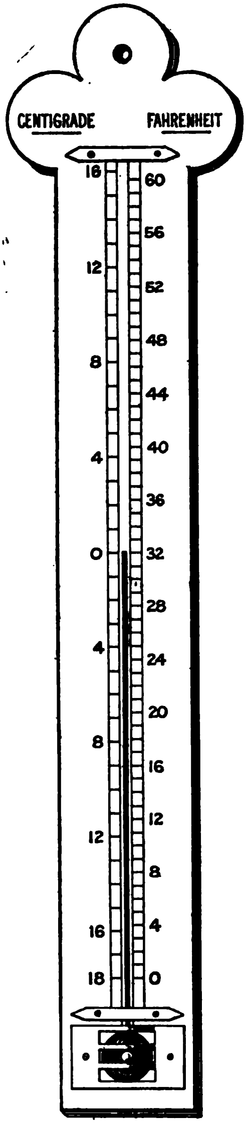


FIG. 27.—THERMOMETER (FAHRENHEIT AND CENTIGRADE)

expands with the warmth, it is forced further along the tube, and when it contracts with the cold, naturally fills less of it. All thermometers are made on the same principle, but they are not all marked on the same scale. According to the one most used in scientific experiments, called the *Centigrade scale*, the point at which ice will just melt to water is marked 0, or zero, and the point at which water will boil here, as 100. Between these two points, therefore, there are 100 divisions, called *degrees*. But in the *Fahrenheit scale*, commonly used in our own country, the Centigrade zero is marked as 32° and the 100 as 212°, so that there are 180° between what are called 'freezing point' and 'boiling point.' In both scales any temperature below zero is reckoned as so many 'degrees below zero,' and in writing, a minus sign (—) is put before the number. In fig. 27, part of each scale (up to 60° Fahr.) is given you on the same thermometer, standing at freezing point; but Fahrenheit is the one we shall use in this book, unless the word Centigrade is specially added.

Questions on Chapter VI.

1. Mention any gases present in the atmosphere.

2. Account for the presence of solid matter in the atmosphere. What difference does it make to it?

3. Explain the expression 'latent heat.'

4. Explain the formation (1) of dew, (2) of fog.

5. What causes a cloud to fall as rain?

6. Describe a snow-flake.

7. Give any proof that air has weight, and state what pressure is caused by it.

8. What are the causes, and what the results of difference of pressure in different parts of the atmosphere?

9. Describe the construction of a barometer.

10. Explain the difference between the Centigrade and Fahrenheit scales in a thermometer.

CHAPTER VII

THE MOVEMENTS OF THE ATMOSPHERE

§ 54. In considering the movements of the atmosphere, or winds, we will first take those that are *constant*, then those that change regularly with the seasons, and may be called *recurring*, and lastly those that appear quite irregular, or *variable*. Now it is clear that the movement of rotation must be more rapid as we get nearer the equator, since there is a greater distance to be traversed in the same twenty-four hours. And the more swiftly anything turns round, the more it tends to get away from the centre round which it turns. You can prove this for yourselves by swinging a stone on the end of a piece of elastic. On the same principle the atmosphere, which is less dense than the land or water of the globe, and therefore less strongly attracted towards the centre of the earth, will stretch out further along the central line of the earth's rotation, so that there must be a greater thickness of it at the equator than there is at the poles, as shown you in fig. 28.

But within the tropics the air is much hotter than it is to the north and south of them, and over the greater part of this belt lie oceans, from which the water is being so rapidly evaporated, that the air above them is often saturated with water vapour. Both these facts will show that the atmosphere must be lighter there than in the more temperate regions, and the pressure of it would be even less than it is, were there not a greater amount of it than there is nearer the poles. As it is, this light air rises above the heavier air to the north and south of the tropical belt, and overflows on to it, thus making two belts of air, heavier than the air between them, and denser at the surface than the air between each of them and the pole, because of its greater height. The exact position of these belts varies at different times of the year, according as the line of greatest heat is north or south of the equator, but on the average the centre of each lies at about 30° north or south latitude.

From these two belts, then, where the pressure is greatest, the air will naturally flow out at the bottom on to the regions where the pressure is not so great; especially towards the central region where we saw that the warm moist air is constantly expanding and rising, and so less able to resist the inrush of heavier air (fig. 28).

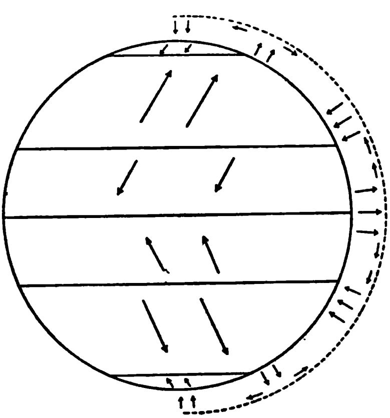


FIG. 28.—DISTRIBUTION OF ATMOSPHERIC PRESSURE

§ 55. You might expect, then, constant winds from each of these belts inwards to the hottest part of the tropics, and outwards to the poles, but as a matter of fact these winds blow not due north and south, but, in the northern hemisphere, towards the north-east and south-west, and in the southern hemisphere, towards the south-east and north-west; those which blow towards the equator are known as the *trade*-winds, and those towards the poles as the *anti-trade*-winds.

To understand why they take this cross direction we must go back to the rotation of the earth, which takes, as you know, twenty-four hours. Now its circumference, we have seen, is 25,000 miles, so that any point on the equator is really moving at the rate of more than a thousand miles an hour; but the further north and south we are, the less becomes the distance we have to cover in order to get round in the same time. This being so, you might wonder why it is that if we take a jump into the air we do not come down some way to the west of the point at which we left the ground, since the earth beneath us has travelled eastwards. The reason is that our bodies have got the same speed or *momentum* as the ground they were resting on. What this means you can tell if you try to jump out of a train when it is moving; you will feel as if you had been pushed violently forward, and perhaps tumble on your nose unless you run a few steps in the direction you were travelling. This is because your body has got the momentum of the train, which is only partially checked by the resistance of the platform under your feet. In just the same way the atmosphere over any part of the earth has the same momentum as the surface, and if it moves towards either of the poles, this momentum will carry it ahead of the air it meets, which is travelling more slowly; but if the same air moves towards the equator, the air it meets and the surface below will have a still greater momentum, and so force it to lag behind. If we come back to our railway carriage we shall perhaps realise this better. Suppose we are facing the direction in which we are going, and open the window to let in some air; it blows right into our face instead of into the middle of the carriage. This is because when it came in through the window it had not got the momentum of the air already in the carriage and lagged behind it, and so seemed to blow in the opposite direction. This important fact, which applies to all winds, is known as *Ferrel's Law*. Now a wind always takes its name from the point of the compass *from* which it blows, so that our constant winds will be, in the northern hemisphere, a N.E. trade-wind from about lat. 30 to the equator, and a S.W. anti-trade-wind towards the arctic region; in the southern hemisphere, a S.E. trade-wind from about the same latitude towards the equator, and a N.W. anti-trade-wind towards the antarctic regions (fig. 28).

But as we get nearer to the poles we find that the air becomes once more rather heavier again; for though there is probably, as we said above, less of it, it is very cold, and hence also very dry, and we know that cold, dry air is heavier than warm, moist air. Here again, then, the atmosphere is pressed outwards till it meets the anti-trade-winds from the lower latitudes, and this has the effect of turning the north-west and south-west winds in each case more to the west. In the southern hemisphere, where there is no land to interrupt its course, the result is a steady, almost continuous, westerly wind.

§ 56. Were the globe completely covered by the sea, the description given of the trade and anti-trade winds would be a fairly complete account of the movements of the air. But in fact you know that the sea surface is broken by the great land masses of the continents, and it will be necessary to grasp clearly the effect of sea and land on the temperature of the atmosphere in order to understand the recurring winds which to a very great extent modify and even reverse the constant winds, especially in the northern hemisphere.

When the sun shines on the land, its rays do not pierce beneath the surface, and comparatively little of its heat is carried downwards into the earth. You know, for example, how cool it is in summer in a cave or tunnel, or even in a cellar. Where, then, does the heat go to? It is thrown back or *radiated* into the air; so when the ground gets hot, the air above it gets hot too. Let us see if this is so in the case of water. Here the sun's rays penetrate much deeper; in fact their effect may be felt to a depth of 500 or 600 feet; in this way the rays get used up, so to speak, so that the surface of the water and the air above it do not become so hot. When, however, the sun no longer warms it, the sea, having stored up its heat beneath the surface, remains warm for a long time, and continues to radiate this warmth into the air, so keeping it from becoming very cold; meantime the land, having given back most of its heat as quickly as it got it, soon becomes cold, and cannot warm the air above it. That is why it is warmer at the seaside in winter, and why we can bathe comfortably in the sea in the autumn when the land near is quite chilly. The result of this difference may be simply stated as follows: *The air above the* *land is warmer than the air above the sea in the same latitude during the winter, and cooler during the summer.* The same difference on a lesser scale may be noticed in the daytime and at night; and the result of it then appears in its simplest form. During the day the warm air over the land rises, and the colder air from the sea pours in to take its place. During the night the air above the sea is comparatively warmer, and the cold air from the land flows in and forces it upwards; so, as a rule, during the day there is a *sea breeze* on the land, and during the night a *land breeze* on the sea.

§ 57. The land and sea breezes are the simplest forms of recurring winds, but the difference between summer and winter on the great expanses of sea and land will naturally cause much stronger and more sustained movements of the atmosphere. In the northern hemisphere the division between sea and land is more nearly equal than in the southern, there being two great continents, Eurasia and North America, and two great oceans, the Pacific and Atlantic. We will examine their effect on the atmosphere, first in winter, then in summer. In winter, then, the two continents will have a cold and comparatively dry atmosphere, especially Eurasia, which is by far the larger, and has in the centre and east a vast stretch of high mountainous tableland which makes it still colder. Over the Pacific and Atlantic, on the other hand, the air will be comparatively warm and moist. At about lat. 30°, or in winter slightly below, comes, as we saw, the northern great belt of high pressure (§ 54); while in the arctic region to the north we have seen that the air is heavier than it is over the warmer oceans to the south of it; so that roughly between lat. 40° and lat. 60°, in the Pacific and Atlantic Oceans, there will be a *basin* of low pressure, surrounded by regions of high pressure. Into these basins the heavier air will steadily flow from all sides, to be in turn made moist and warm and rise, leaving room for more to flow in. This rising of the moist warm air will be further helped on by two causes. First, at a certain height, as we have seen, clouds will be formed, which serve, as we know, to prevent the radiation of heat, and so keep the surface of the ocean warm. Secondly, the condensing of these clouds will still further warm the air by releasing latent heat (§ 46), and so will cause it to rise still higher. These basins, where the air is continually being drawn upwards, are called *cyclonic areas*, for a reason we shall understand later.

§ 58. All this time the cold dry air over the two continents will press outwards on all sides, and where, as in the east of Eurasia, it is much heavier even than the high-pressure belt to the south, it will counteract its pressure, and so reverse the anti-trade-wind, but it will naturally blow most strongly towards the cyclonic basins on each side. These regions, where the heavy air is being continually pressed downwards and outwards, are called in opposition to the others, *anticyclonic* areas.

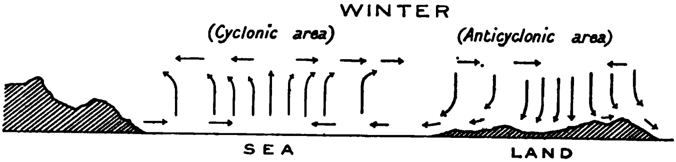


Fig. 29.—Effect of Land and Sea on Pressure

You might be inclined to ask what becomes of the air which keeps rising in the cyclonic areas, and where that comes from which is always pouring out at the bottom of the anticyclonic areas. Well, the two questions answer one another. The rising air at last reaches a height where the pressure round it ceases, and the surrounding air is being drawn downwards over the anticyclonic area; it naturally therefore flows outwards till it reaches the top of these areas, when in turn it is drawn downwards. So, by means of *upper currents* in the atmosphere in the opposite direction to the winds at the earth's surface, the regions of low pressure are continually feeding those of high pressure, and so keeping up the circulation of the air (fig. 29).

In summer the conditions we described above will, of course, be reversed. The great table-land of Eurasia, and to a lesser degree the central plains of North America, will become intensely hot, and all this heat will, we saw, return

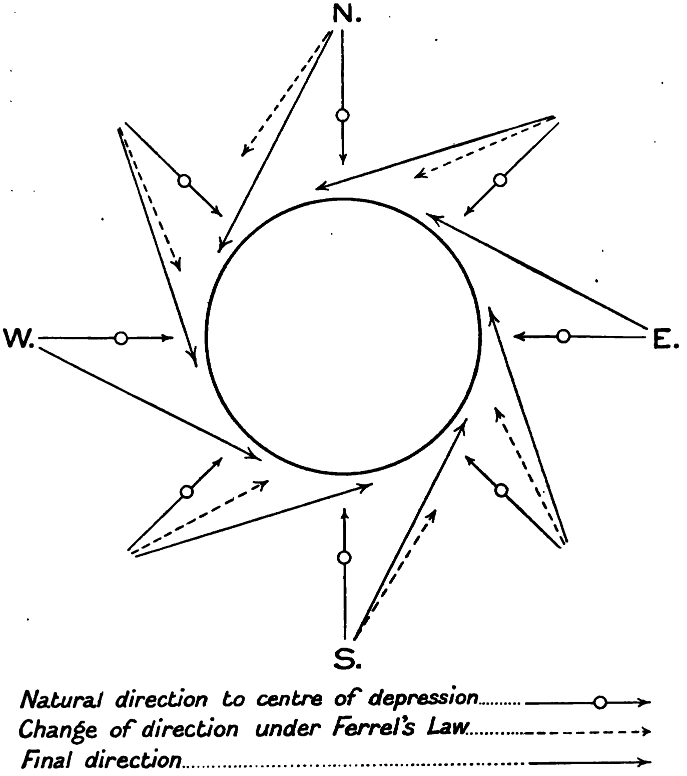

N.
W.
E.
S.
Natural direction to centre of depression
Change of direction under Ferrel's Law
Final direction

FIG. 30.—ILLUSTRATING FERREL'S LAW OF WINDS

to the air, which will therefore rise, breaking up the belt of high pressure, and overflow into the comparatively cool air above the oceans. These will now have become anticyclonic areas, joining on to and strengthening the remains of the high-pressure belt, which in summer shifts northwards;

redoubling the force of the trade-winds to the south; and pouring out over the two cyclonic areas of the continents. We have, then, a regular system of winds changing with the seasons, and where these blow most steadily they are known as *monsoon winds*.

§ 59. Now it has been observed that the winds do not travel straight out from an anticyclonic area to the surrounding regions of lower pressure, nor straight in to a cyclonic area from the regions of higher pressure, but in both cases they make a curve like the sparks of a 'catharine-wheel.' This, if you think of it, is only another illustration of the working of Ferrel's law. Suppose fig. 30 represents a cyclonic area, then the winds coming in from the north and south will, as we saw in the case of the trade-winds, be turned or deflected to the north-west and south-east; these in turn will push those coming from the west and east, and force them to join in the general circular movement, from which the cyclone gets its name. The same thing will happen round the anticyclonic areas, only then the wind will be travelling outwards in the same direction as the hands of

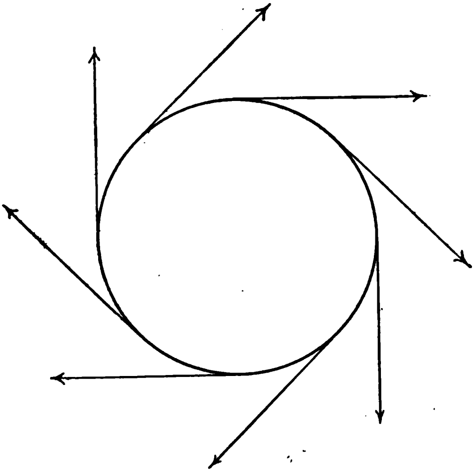


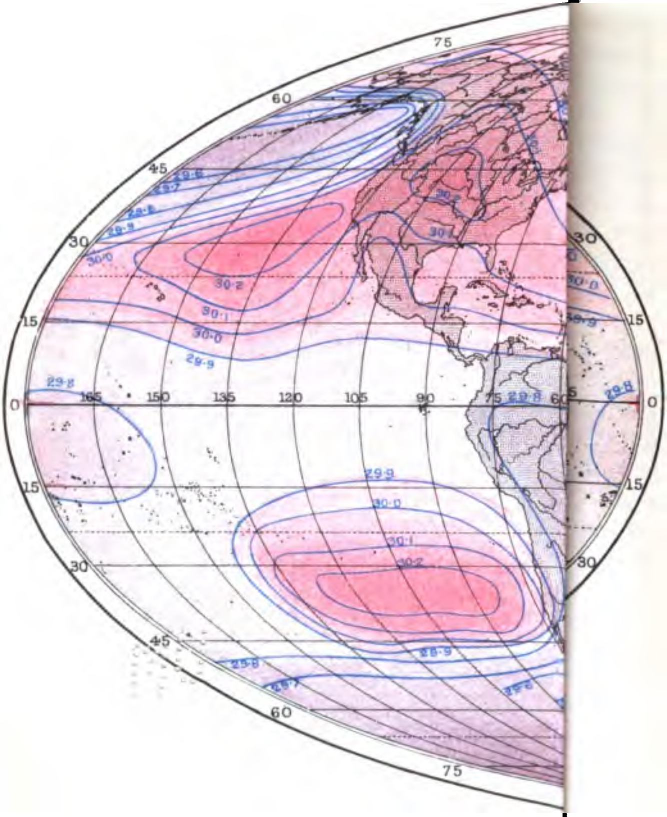
FIG. 31.—ANTICYCLONES

the clock (fig. 31), and not inwards in the opposite direction, as in fig. 30.

§ 60. So far we have only dealt with the winds of the northern hemisphere. In the southern hemisphere the division of land and water is far more unequal. The two comparatively narrow peninsulas of South America and South Africa, and the island-continent of Australia, divide the expanse of sea into the South Pacific, South Atlantic, and Indian Oceans; and during the summer (that is, of course, our winter), when the southern belt of high pressure has shifted down to about lat. 35°, these three land masses become cyclonic areas, cutting the high-pressure belt into three broad anticyclonic areas over the three oceans. But in winter, when the belt has shifted northwards (lat. 25°), it becomes once more continuous round the globe.

We have now sketched out the principles which govern the recurring or seasonal winds, and you will better understand them by studying very carefully the two charts given you, with the areas of high and low pressure clearly marked, one for summer, the other for winter. The British Isles, as you will see from these, are just on the border between a great cyclonic and anticyclonic area, which almost change places in winter and summer, but in either case they bring, you will notice, a south-west wind, which is therefore the prevailing wind with us. The great cyclonic and anticyclonic areas, then, account for the prevailing winds at different seasons of the temperate zones, yet this does not mean that the wind blows continuously from one direction, but only that it does so more often than from the others. In fact, as you know in the case of our own island, the wind is constantly shifting from one quarter to another, sometimes bringing storm and rain, and sometimes fine weather, as well as great changes in the temperature. We must therefore try to learn something of the variable winds to which this is due.

§ 61. These are most commonly *cyclones*, formed on the same principle as the great cyclonic areas we have spoken about, but having this great difference that, whereas the cyclonic areas remain fixed for a whole season in one place,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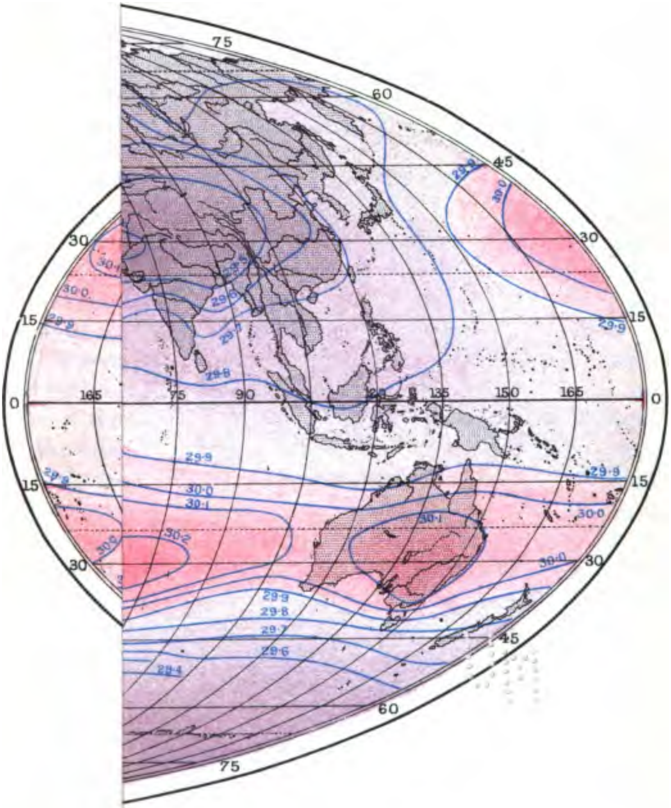
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the cyclones proper are continually travelling in one direction. No doubt they arise from the air in one place becoming hotter or moister than in the surrounding regions, and consequently lighter, when the heavier air round will pour in as shown in fig. 30; but why the whole whirling mass travels along in one direction, like the eddies in a stream, is not very clear. This direction is always westward, and inclines towards the north in the northern hemisphere, where they are more common than in the southern. The usual starting point seems to be the North American continent, whence they move across the Atlantic about the pace of a slow train, most frequently bearing northward, past the north coast of Scotland to the north-west of Norway. Sometimes, however, they take a more southerly course, keeping to the south of the British Isles and passing over central Europe and on to Siberia, where they appear to die away.

This general direction has, of course, nothing to do with the direction of the winds which are blowing in towards the centre of the eddy, so that as it passes over any particular spot the wind will at first be from the south or south-east, gradually veering round to the west, and after it has passed by, coming from the north and north-east. So you see it makes a great difference to us whether the cyclones pass to the north of us or to the south, since in the first case we shall get their warm southerly winds, and in the latter case the cold northerly ones.

The strength of these winds will depend on the size of the eddy. If it is a very big one—and sometimes they cover thousands of miles—the winds will not be so strong as in the smaller ones, if the difference in the weight of the air in the middle, or what is called the *depression*, is the same. It is therefore the smaller ones that cause the violent storms. Again, the air which is sucked into the middle is constantly rising, and as it does so it cools, so that its moisture is condensed and drops as rain. That is why we associate storms with heavy rain, and this with a 'low barometer.'

These cyclones, as we have seen, belong chiefly to the north temperate zone, and are specially interesting because of the great influence they have on our weather.

§ 61*a*. In the tropical regions whirling eddies of a rather different character occur. Instead of being measured by some hundreds or even thousands of miles, they are usually only some hundreds of yards across; and as we found that the smaller the cyclone the more violent the wind, we shall not be surprised that the wind in these is more violent than anything we ever experience in this part of the world. They are called by many different names; in the West Indies they are known as *hurricanes*, in the south-east of Asia as *typhoons*, and in North America as *tornadoes*. These hurricanes or tornadoes travel much faster than the larger cyclones, and the winds blowing into them are so violent that everything—trees, houses, bridges—are swept before them, and so strong is the indraught of air in the centre that strong walls are sucked in just as a piece of paper is in front of a grate when the fire begins to blaze up; and even heavy metal objects are carried *upwards*. Fortunately these tornadoes do not travel continuously along the ground but bump along it, so to speak, sometimes passing harmlessly overhead, then striking the earth again and causing more havoc. Where they pass over the surface of the sea the water is sometimes sucked in just in the same way, causing what is known as a *waterspout*. These may do even more damage than a tornado on land, for the water is sometimes carried bodily on to the land, sweeping everything away in a deluge. This happened many years ago in the delta of the Ganges, when thousands of people perished.

Questions on Chapter VII.

1. Account for the existence of two belts of high pressure, and state where they are found.
2. Explain the facts expressed by Ferrel's law.
3. What is an anticyclonic area, and how is it caused?
4. What is the character of a cyclone?
5. What different kinds of wind are there? Give an example of each.

CHAPTER VIII

FORMS OF WATER

§ 62. In trying to learn something about the history of the earth's crust, and how it came to be as it is now, we often had to refer to the action of water. You will remember that we took the history of a drop from the moment it came down to the earth in the form of rain, till it found its way to the sea, and was drawn up again into the atmosphere as an invisible vapour. We have also seen that this vapour is always present in the atmosphere, though in very different amounts, and that when there is more of it than the atmosphere in any place can hold, it condenses into the minute drops which form cloud, mist, and dew. Again we know (§ 36) that there is water in the ground beneath our feet as well as in the sky above us: in fact, there is probably no rock so hard that water cannot get through it in some quantity, however minute; and we shall find later that water is absolutely necessary to the life of all plants and animals; that is, of all living things on the earth.

So, then, there is water everywhere: in the sky, in the rocks, in the leaves of plants, and in our own bodies; and it has been well described as the 'life-blood' of our planet. In this chapter we are only concerned with the different forms in which it collects on the earth's surface: these are chiefly springs, rivers, lakes, snow-fields and glaciers, and finally oceans.

§ 63. You are all familiar with some river or stream, and have watched it flow, whether slowly or swiftly, along its bed; and it may often have occurred to you to wonder where the water comes from, and why it constantly flows onwards, without coming to an end. To answer these questions, we must recall what we learned about the formation of the earth's crust. We found that it was made up of different kinds of rock, almost always in layers or strata. Some of these, such as sandstone, gravel or chalk, allow water to pass more freely through them, and are called *porous*; others, such as clay and granite, only allow very little to pass, and are called *impervious*; but even these, especially near the surface, usually have cracks and fissures through which the water can escape. Let us suppose, then, that a layer of sand or chalk lies on the top of a layer of clay. The rain or melted snow will quickly trickle through the upper layer, and collect at the top of the lower one. What happens to it then will depend on the slope, or lie, of the stratum below. If this is straight or 'horizontal,' as in fig. 32, the water will ooze out at the edges in muddy springs, which will find their way into streams or pools below. If the resisting layer slants, as in fig. 33, the water will naturally flow down in the direction of the slant, and pour out where the lower stratum comes to the surface. But this stratum may not come to the surface at all; it may end in what is called a *fault*, such as is shown in fig. 34, in which case the water will collect in the angle formed by the fault with the sloping stratum, and if there is enough pressure of water

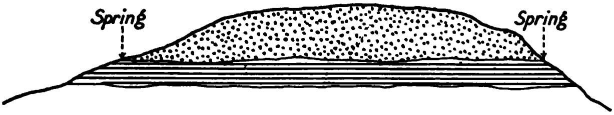


Fig. 32.—Springs

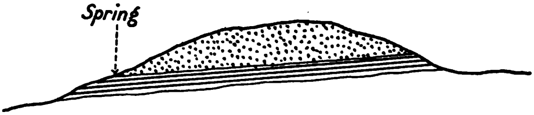


Fig. 33.—Springs

along the upper slope of the porous layer, bubble up to the surface at this point.

Even where we do not see any springs, we know that there is water below the surface of the ground, from the wells which are to be found almost everywhere, even in deserts like the Sahara, which get their supply from the water collected in the manner described above, though it cannot reach the surface. In the same way, when a mine is sunk, arrangements have always to be made for draining out the water, and if these fail, the mine is soon 'flooded.'

Lastly, supposing the impervious stratum lies on the top of the porous strata, then the water will collect below the top stratum, and can only be brought to the surface by wells sunk through it. If the strata beneath form a kind of basin, as sometimes happens, the pressure on the water in the centre of the hollow will make it shoot up to the surface if a boring is made near the centre of the basin through the upper impervious layer. Fig. 35 gives you an idea of the arrangement of the different strata under London, and shows you where the water came from which originally made the fountains of Trafalgar Square.

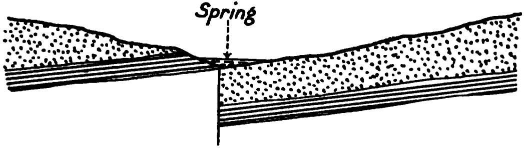


FIG. 34.—SPRING AT A 'FAULT'

§ 64. We also saw, you will remember, that in passing through the soil, the water underwent a change (§ 32), and exchanged some of its oxygen and carbonic acid for mineral salts. Where large quantities of these salts are present in springs they are called *mineral springs*, such as those containing compounds of sulphur or iron, and these are often valuable for curing invalids. Many again contain the salt made of sodium and chlorine which we use with our food, and is what we commonly mean when we speak of 'salt.'

These are called *brine springs*. In limestone regions the water usually has a large proportion of carbonate of lime, and it is the dissolving of this by water which causes the great caverns and underground tunnels sometimes found in such regions, as for example in Derbyshire.

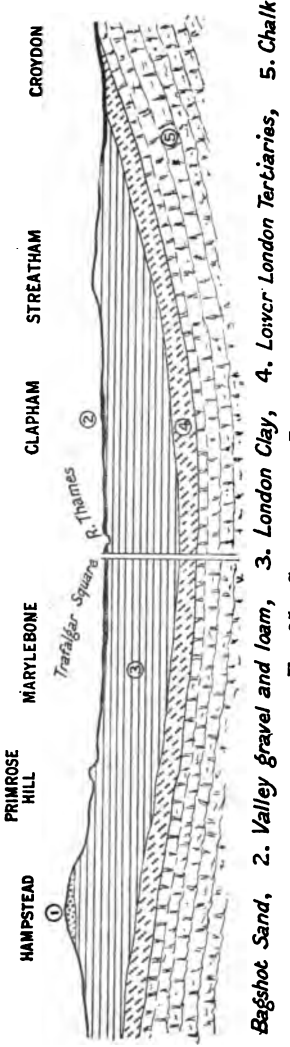

HAMPSTEAD
PRIMROSE HILL
MARYLEBONE
CLAPHAM
STREATHAM
CROYDON
Trafalgar Square
R. Thames
①
②
③
④
⑤
1. Bagshot Sand, 2. Valley gravel and loam, 3. London Clay, 4. Lower London Tertiaries, 5. Chalk.

FIG. 35.—STRATA UNDER LONDON

Though most springs send up very cold water, yet in some it is warm or even quite hot, as in the famous *geysers* of Iceland: this means that they must have risen from a very great depth (§ 28).

Springs are not the only sources of rivers, as we shall find, but at least they will help you to understand the origin of our own, as well as of many other much bigger rivers than are to be found in this country, such as the Danube and the Mississippi; and you will now perhaps be able to see how this account of the origin of springs helps us to answer the question why a river continues to flow without coming to an end. For it is evident that if the water has had to travel through layers of rock, sometimes for great distances, it will take a long time to reach the spring where it comes to the surface; and so it will rarely happen that all the water in those strata is exhausted before more has fallen as rain or snow, to take its place. Thus a constant supply is kept up; whereas if the river had no springs to feed it, but merely collected the water on the surface of the ground, it would be swollen up after every shower, and completely dried up by the first spell of fine weather.

§ 65. We must now try to understand what are meant by a river valley and basin. You know that the surface of the land is rarely quite level, and the folds in it are sometimes sharp enough to be plainly visible as hills or mountains, but more often so gentle, that in travelling along the land our eye cannot possibly detect them. But if we cannot, water always can; and so all the rain that falls within the sides of one of these folds or hollows, and all the springs which rise in it, send their water down to the 'trough' of the hollow, and so it is carried along in the direction in which the trough slopes. That is why a river is said to *drain* its basin—for this is only another name for the hollow—and the trough is, of course, the river valley. This does not mean that river basins are at all regular in shape; one often leads into another, in which case their two rivers will join, the lesser one being called a *tributary*; nor is it always easy to tell at a glance where the division comes between one basin and another, the line being often a very intricate one. This division is called a *water-parting*, and it may be described as the line of greatest continuous height between two depressions or basins. It is important to notice that it does not necessarily follow the highest mountains or hills in any region, since these may rise entirely within one of the depressions, and not form part of any continuous line of height.

The first work, then, of a river is to drain the water from a certain region called its basin, by collecting both what comes to the surface in springs, and also what trickles along the surface into its trough or valley; though the greater part of this latter is evaporated into the atmosphere before it actually reaches the river.

§ 66. But we also know that rivers are always carrying part of the rocks down with them (§ 31), and that the steeper their course, and the faster they flow, the greater is the amount of solid matter they can hold. And so where the trough of the depression slopes more gently, and the river begins to flow more slowly, the heavier part of its load will have to be dropped, first as gravel, then as sand or mud. In this way the bottom of the trough—that is, the river-bed—will in time be filled up, making the river broader and shallower; and at last causing it to spread out over the trough, and perhaps even find a new bed altogether. In any case the level of the whole trough or valley must gradually be raised, and the lower part of nearly every river valley presents a flat surface of rich fertile soil, which has been continually accumulating there, and through which the river slowly winds its way. But naturally this filling up of the river bed, and consequent overflowing of the stream, would be highly inconvenient if there were many people living on or near its banks, and still more so if there were any large towns on it; so that such rivers as the Po in Italy, which, with its many tributaries, brings down a vast quantity of sediment from the high mountains at the edge of its basin, and has in former ages made the great fertile plain of Lombardy, have their banks built up artificially, in proportion as they raise their bed, to prevent them overflowing; and in some places the bed of the river is actually above the level of the towns which were once on its banks.

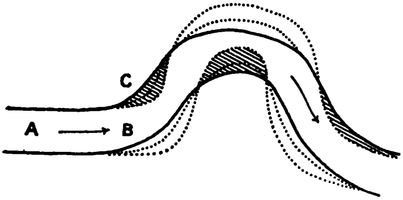


Fig. 36.—River Windings

§ 67. We spoke just now of the river winding along its valley; and you will almost always find that the more level that valley is, the more the river winds. The diagram here given will help you to understand why this is so. There a stream is represented (fig. 36) flowing in the direction of the arrows, and having at A the strongest current in the middle. When it turns the corner at B, this current is carried up against the bend, and gradually scoops it out still more; while at C the current will not be so strong, and so cause more sediment to be deposited there. The same thing will happen at each bend, so that in time the river bed will follow the course of the dotted lines, making a series of loops. In some cases, as for example in the Mississippi, the two sides of a loop may even cut through into one another, and form an island, or cause the river to desert the old channel altogether, and leave nothing but a pool, or quite dry ground, where it once flowed.

§ 68. On the other hand, where the river flows swiftly, which it usually does in the earlier part of its course, it gathers up more solid matter than it deposits, and wears away the corners in its channel as well as the bends, since it has force enough to sweep away obstacles which would have turned a slower-going river aside. It will thus have a straighter channel, and also, as a rule, a deeper one; for not only does a swift stream gather up more sediment, but it also rolls comparatively large blocks along its bed, which help to cut it deeper; these are the pebbles we so often see at the bottom of a clear stream. When the course of our river lies over a stratum of very hard rock, this power of cutting out its bed becomes very noticeable, and produces what is called a *gorge*. One of the most famous is the gorge made by the Colorado river in North America to a depth of more than a mile through solid rock; and there are some beautiful gorges, though on a much smaller scale, among the Alps in Switzerland.

Sometimes, again, it happens that the bed is in a stratum of hard rock, lying over one of softer material. If the former comes to an end, leaving the latter exposed at the surface, this will easily be worn away, but as long as it is protected by the harder rock above, it will resist the action of the water. The result will be a sudden dip in the level of the channel, where the hard stratum ends, till at this point the water will fall sheer down, making what is called a *waterfall.* The ledge over which it falls will in time wear away also, but not before the softer rock underneath has given way too; so that the waterfall will remain, only it will slowly shift further up the stream, leaving a gorge below, where the rock has been worn away (fig. 37). One of the largest waterfalls is on the Niagara river, between lakes Ontario and Erie.

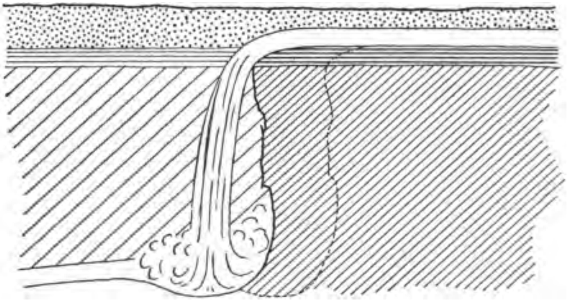


FIG. 37.—A WATERFALL

§ 69. We have now learned something about the solid matter which is gathered up, for the most part, early in the career of a river and deposited in its later stages; but some of this sediment is carried on by the river to its mouth, that is to the point where it flows into the sea. What happens to it then will depend on the currents and tides (about which we shall learn in the next chapter) in that part of the sea. If these are strong—as, for example, in the Atlantic Ocean—they will carry away and scatter the sediment; but if there is no strong current, and only a slight rise and fall of the tide—as, for instance, in the Gulf of Mexico, or the Mediterranean Sea—the sediment will fall as soon as the current of the river is stopped by the sea, and remain there until in time the sea at that point is filled up. The river will now have to make its way through the newly formed land, and the same process will be repeated farther out. But the sediment will be heaped up most in the centre of the river mouth, and when it reaches the surface, the river will have to divide and flow round it. There will thus be two mouths instead of one, and as these two get filled up, they will probably divide again, so that we shall get a bigger and bigger tongue of land, cut through by numerous branches of the original river finding their way to the sea in different directions, and shaped something like a half-opened fan (fig. 38). When the Greeks first noticed this at the mouth of the river Nile, it struck them as being like their letter *delta* (Δ), so they gave it that name, which has remained, and been applied since to all other river mouths like it.

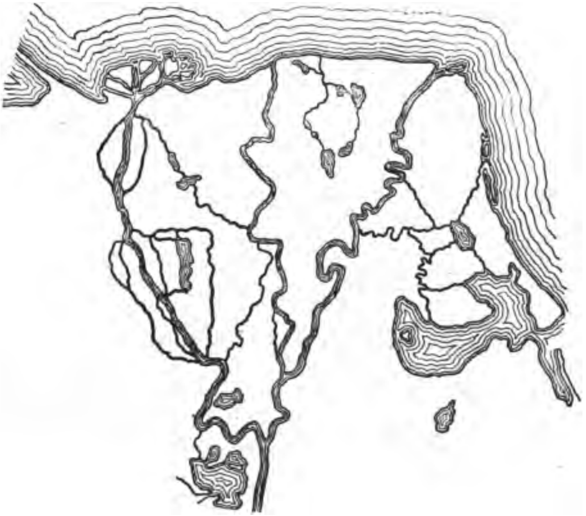


Fig. 38.—A Delta (the Danube)

§ 70. So far we have taken for granted that the trough had an uninterrupted slope down to the sea. We must now consider what will happen if it comes to an end, and the basin is raised all round its edge. Then it is clear that the water which flows in will not be able to get out, and a *lake* will be formed. Now this may happen under three very different conditions. The basin may be a mountain valley blocked up at both ends; or it may be a shallow fold in a plain, or comparatively flat region; or, lastly, it may be really the bottom of a basin which does not connect with any of the oceans, and may be even below sea-level.

In the first case a deep *mountain lake* will be formed, following the line of the valley, and therefore, usually, long and narrow, though not necessarily so. This will go on filling till the lowest point in the rim of the basin is reached, when the water will overflow and continue its course as a river, and the deeper it cuts the channel where it flows out, the lower the level of the lake will become. In time this channel may be cut down to the level of the bottom of the lake, and nothing be left of the latter except the sediment deposited on its floor, which will now become a strip of fertile valley (fig. 39). There are many of these mountain lakes to be seen in Switzerland and the north of Italy, and also many fertile plains which were once the floors of former lakes. In Africa and Asia there are some lakes formed, not so much in a mountain valley, as in a deep hollow in a table-land, which have their outlet in the same way. Such are Lake Baikal in Asia, out of which flows a tributary of the great river Yenisei, and Lake Victoria Nyanza in Africa, the main source of the river Nile.

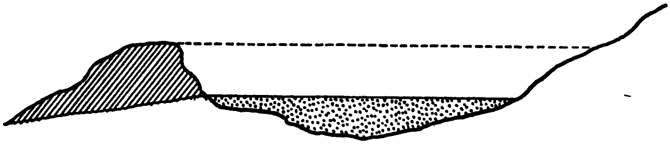


FIG. 39.—LAKE FLOOR

§ 71. The second kind, which may be called *plain lakes*, as opposed to mountain lakes, will be, as a rule, broader and shallower; but provided the downward slope continues again in some direction, the water will overflow, as in the mountain lakes, and continue its course as a river. In fact, lakes of this kind are sometimes only a widening out of the river bed, such as may be seen in the course of the Shannon, in Ireland. More typical examples of plain lakes may be seen in Sweden, Finland, and the north-west of Russia, where one—Lake Ladoga, which drains into the Baltic by the river Neva—covers over 7,000 square miles.

§ 72. In the case of those lakes which lie at the bottom of a true inland basin, no outlet, of course, is possible, and the water can only escape by evaporation. Such lakes will alter very much in size, according to the amount of water brought in at different seasons by the streams that feed them; also the evaporation will be much greater in summer than in winter, so that there will probably be a large circle of marshy land round them, which is sometimes under water, and sometimes dry. Now as these lakes, like the sea, are only drained by evaporation, it follows that they also must become more and more salt (§ 32). One of the largest drainage basins on the globe is the inland one in the middle of Eurasia, at the bottom of which lie the Caspian and Aral seas, which must at one time have formed one great sheet of water. You see, then, that the water in this basin must have got much less, and this is the tendency of all *salt lakes* and seas; for as their floor gets filled up with sediment, they will become broader and shallower, and the evaporation will then go on faster, while the inflow of fresh water remains the same, so that at last nothing but a salt marsh will be left where the lake once was. If, however, this lies in a deep natural hollow, as the Dead Sea does, for example, in Palestine, before this happens the water will have become saturated with salt—that is, it will contain as much as it can possibly hold in solution; after which all that comes into it has to be deposited in a solid form, and so a crust of salt gradually forms on its floor. Such lakes must have existed in former ages where salt mines are now found, as at Droitwich and Krakow.

§ 73. We must now look for a moment at another form in which water is abundant in certain parts of the earth's surface, and which forms the other great source of rivers mentioned in § 64.

You know that mountains above a certain height are always covered with snow, except where the rocks are too steep for it to lie on them; and the height in any region at which the snow ceases to melt away entirely, even in summer, is called the *snow-line*. The height of the snow-line will naturally vary according to the latitude of the region. The snow then gets piled up on the rocks to a great depth, forming snow-peaks and *snow-fields*; but partly by the wind, partly by the melting of the surface in the sun, and partly by its own weight, it is being constantly driven or pushed into the hollows, sometimes, indeed, suddenly in great masses, as what are called *avalanches*. Then as it melts it forms little streams, which find their way down into the valleys, and make the mountain torrents which foam and thunder over the rocks which try to bar their way.

But when great masses of snow get pressed together in a trough from both sides, the pressure turns the snow into ice, which is made still more compact by the melting snow at the surface trickling through and freezing again below. This ice then, being continually pushed from above, will flow down the trough as an ice-river, called a *glacier*. This will sound very strange to you, for you will say that only liquid things like water can flow and be said to make a river; but though the ice is solid, the glacier does move very slowly down the trough of the hollow, and so may be said to flow. When it gets far enough down the valley it melts faster than it moves, and so comes to an end, and out of it pours the stream which comes from the melted ice on the surface, which has made its way through great cracks and holes to the bed, and there bored a tunnel through the ice. In this way many great rivers—as, for example, the Rhone in Europe, and the Ganges in India—have their beginning.

In the arctic regions the snow-line we spoke of comes down to the sea-level, so that the 'ice-rivers' actually flow into the sea. In Greenland especially, which is a very lofty table-land covered with snow, the glaciers reach to a great depth, and as they push their way into the warmer sea, the ice breaks off in great masses called *icebergs*, which float along with the ocean currents, till they gradually melt away in the warmer parts of the ocean.

Questions on Chapter VIII.

1. Describe the formation of different kinds of springs, illustrating your answer with diagrams.
2. Mention and account for any peculiarities in spring water.
3. Explain what is meant by a water-parting.
4. What are the main differences between a rapid and a sluggish stream?
5. Explain the occurrence of a waterfall.
6. Describe the formation of a delta.
7. What different kinds of lakes are there? Give some of the characteristics of each.
8. What is a glacier?

CHAPTER IX

THE SEA

§ 74. If we divide the whole surface of the globe into seven parts, an area equal to five of these would be covered by sea, leaving only two of dry land, so that there is two and a half times as much sea as there is land. We saw also that the sea differed from most of the other forms of water described in the last chapter, in the large proportion of salts dissolved in it, making it what we call 'salt' as opposed to 'fresh' water. These amount roughly to about 3½ per cent. of its weight; that means that if you had a cistern holding exactly a hundred pounds' weight of sea water, and evaporated it all away, there would be about 3½ lbs. of salts left at the bottom. If we went on to *analyse* these—that is, to find out what they were made of—it would be found that many different minerals were contained in them, but that by far the greater part consisted of the compound of sodium and chlorine which we commonly speak of as salt. There are only two others that we need mention: calcium carbonate, or carbonate of lime, which we saw was so largely dissolved from limestone by rivers and springs (§ 64), and silica, a compound of oxygen and silicon, which is only dissolved in very minute quantities by water. But though the calcium carbonate only amounts to a hundredth part of the common salt, it is from it that all the shells are built which you find strewn on the shore, as well as the new beds of limestone which are being formed under the sea (§ 33). The far smaller amount of silica supplies the material for the forests of sea-weed which grow on the floor of the shallower parts of the sea.

Besides these salts the sea contains a certain amount of oxygen, and it is this which enables the fishes to breathe though they are under the water.

§ 75. Another important fact we have already learnt about the sea is that its temperature varies much less than that of the land, since the heat of the sun is much more diffused through it; and, as in the case of the atmosphere, the question of temperature has much to do with that of density. Water, like air, is heavier as it gets colder, but there is one point to be carefully noticed. This increase of density only goes on up to a certain point, and as soon as water cools below 39°, it begins to decrease in density, that is to get lighter again, and continues to do so till it freezes, which fresh water does, as we saw, at 32° (§ 53). If this were not so, ice, instead of floating on the water, would always sink to the bottom of it; and indeed, as the coldest water, being heaviest, would always be at the bottom, ice would be formed there first instead of at the top of any sheet of water. Now, as the warmth of the sea comes almost entirely from the sun's rays, as we go deeper down the temperature gets colder and colder, and until this reaches 39°, the density at the same time gets greater and greater. The density of the cold deep water is further, though very slightly, increased by the pressure of the mass above it.

Lastly, it must be noted that salt water does not freeze at the same temperature as fresh water, but 4° lower, that is at 28°, and the water at the bottom of the deeper oceans is often found to be colder than the freezing point of fresh water.

§ 76. We must now find out something of the movements of this great body of water, and these are, roughly speaking, of three kinds: one, that of the *tides*, is connected with what we learnt in our second chapter on astronomy; the other two, *waves* and *ocean currents*, depend on what we learnt about the atmosphere.

Turn for a moment to § 19, in Chapter II. There we found that the plane of the moon's orbit is nearly the same as that of the earth, and in fig. 16 some of the positions of the moon were given you in relation to the earth and the sun. Now turn still further back to § 9 in Chapter I., where certain facts, which we saw were always true, were expressed in what is called the 'law of gravity.' From this you will understand that both the moon and the sun attract the earth, and are attracted by it. If the earth's crust were soft and 'plastic' it would bulge out in the direction of either of them, and still more if the direction of both were the same. The solid earth, however, is 'rigid,' and cannot do so, but the sea, which covers as we saw five-sevenths of its surface, is plastic and does so. The rigid mass of the earth is also attracted, though to a lesser extent, and so in its turn is drawn bodily away from the water on the opposite side, which therefore bulges out too, though not quite as much as in the direction of the attraction (fig. 40).

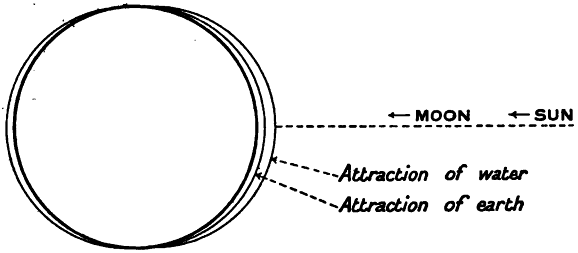


FIG. 40.—TIDES

First of all, then, which attracts it most? The sun is of course much larger, but the moon is nearer, and as the attraction depends on both these things, it comes about that the moon's attraction outweighs that of the sun in the proportion of about nine to four. In its journey round the earth the moon is sometimes pulling on the same side as the sun, sometimes in exactly the opposite direction, and in between these times, of course, at a greater or smaller angle (fig. 16); so that the water will be drawn outwards in the direction of the moon, and if the sun is pulling in the same or the opposite direction, this bulging out will be much greater. On the other hand, if it is pulling at right angles to the moon the two will counteract each other to some extent, and the bulge will be less. This explanation gives you only the main forces at work; a full explanation of the tides would be very hard to understand.

§ 77. As the earth turns completely round in twenty-four hours, this bulge in the water will seem to travel round in the opposite direction, though it is the earth which is really moving. So when any place has come round to the line where the bulge or crest of water is greatest, we say that it is *high tide* there; when it comes to the line at right angles to that of high tide, and so to where the water has been most drawn away, we say that it is *low tide*. Therefore if the moon were standing still there would be high tide at any point on the earth once every twelve hours, and low tide half-way between each high tide. But we know that the moon is also revolving round the earth, and takes twenty-eight days to do so. It travels in the same direction as the earth, consequently by the time the same point has come round to where it was high tide before, the moon, and with it the tide, has moved round one twenty-eighth part of

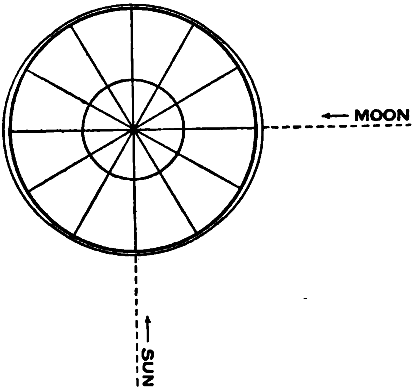


FIG. 41.—NEAP TIDES (POLAR VIEW)

a circle, and it will be rather more than fifty minutes before our point comes up to it again. So that high tide is about fifty minutes later every day for exactly the same reason as we saw that the moon rose fifty minutes later every day (§ 20).

In fig. 40 the moon was represented as pulling in the same direction as the sun, but each day will bring it to a greater angle with the line of the sun's attraction, so that, as we saw, the tides will get less, till at the end of seven days the two will be pulling at right angles, and the tides will be smallest (fig. 41). From this point they will become greater till the moon and the sun are opposite one another, (fig. 42), when they will be as big as they were when the two were pulling together. These highest tides which occur at intervals of a fortnight are called *spring tides*, and the lowest ones in between them *neap tides*.

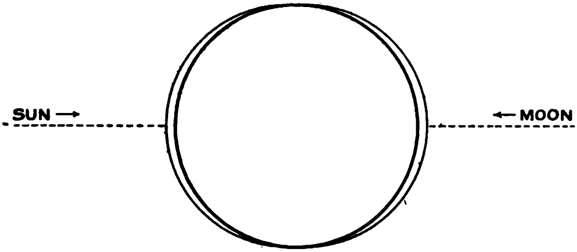


FIG. 42.—SPRING TIDES

§ 78. So far we have treated the question of the tides as if there were an even expanse of sea all over the globe, which of course is not the case. Over a great part of the Pacific Ocean, it is true, there is a fairly regular tidal wave moving from east to west; but elsewhere the various land masses that separate the oceans, and in places the shallowness of the sea, both interfere with its direct course. The land masses change its direction, so that in the Indian and North Atlantic oceans the wave is turned northwards, and in the latter even eastwards, instead of continuing westwards. Shallow water acts as a brake and makes the wave travel more slowly. The difference in the time of 'high water' at different points on our own coast illustrates these two facts very well. Thus, for example, the tidal wave that reaches Bristol at midnight, does not get to Liverpool till four o'clock in the morning, and part of the same wave in the Atlantic goes round the north coasts of Ireland and Scotland, reaching the Firth of Forth at eight o'clock, while of the other part, which came to Bristol at midnight, some had to travel through the English Channel, reaching London Bridge soon after seven o'clock. So the tidal wave circles the coast, travelling in every direction but its true westerly one.

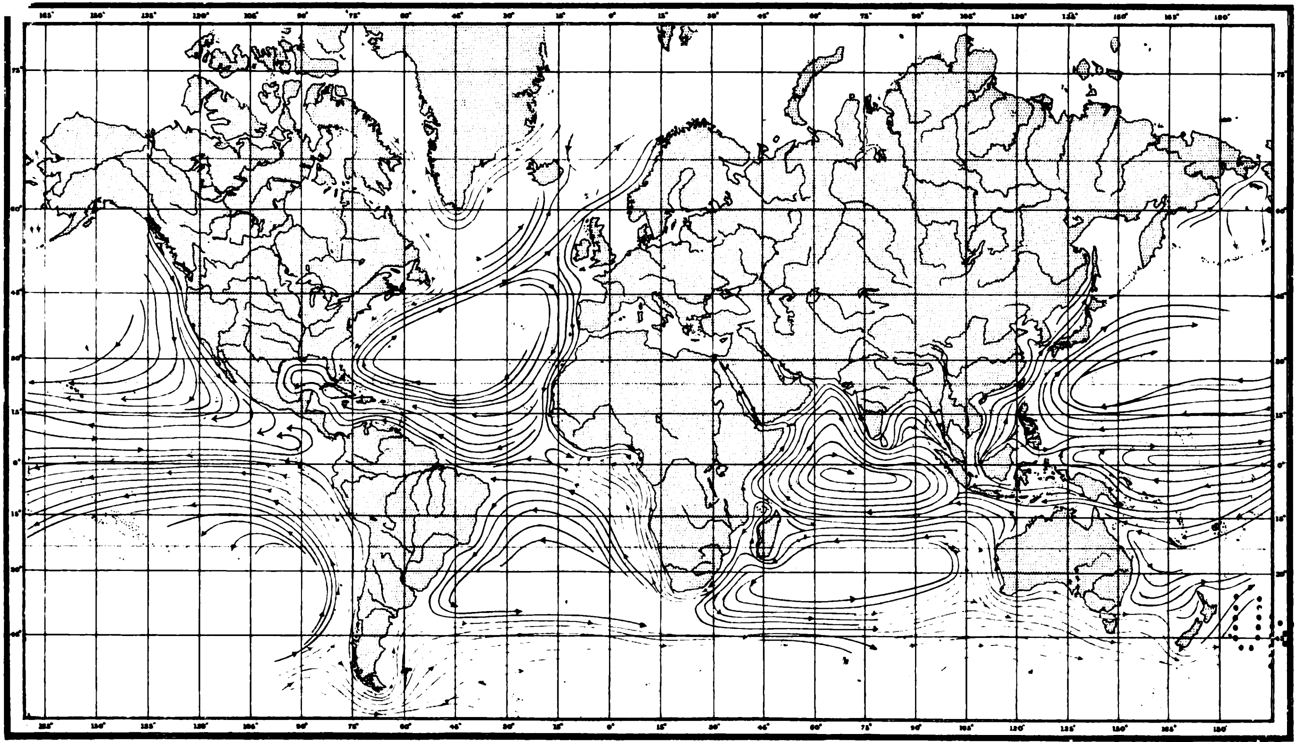
It is important to remember that in the open sea, when we speak of the tidal wave as moving in a certain direction, we really mean that the water along a certain line is drawn upwards, and gradually falls again as the water is drawn up at a line further on; so that *the actual movement of the water is up and down, not along the surface. This is true of all waves in the open sea.* In exactly the same way, when you throw a stone into a pond, the rings in the water seem to travel outwards to the edge of the pond, but if anything is floating on the water you will see that it is not carried forward at all, but only bobs up and down as the rings pass under it; and you can notice the same thing if you are in a boat, and a steamer passes you, making a wave. It is only when the water becomes too shallow for the wave, and the lower part is in some way stopped, that the top, as it were, tumbles over and rolls along. So that along the shore the tide does really advance and recede.

§ 79. It is this movement of the tide when it comes near the shore that chiefly concerns us. How the movement of water up and down, as we have described, becomes changed into a movement backwards and forwards over the surface, it would be difficult to explain; but its effect is very great, and depends on the character of the land which forms the shore. If this forms an inlet or gulf, the incoming wave will be forced into a narrower and narrower space, and will in consequence have to rise to a greater height than the original wave in the open sea. Thus in the narrow bay of Fundy the tide sometimes rises as much as seventy feet. Again, if the shore slopes gradually down into the sea, the rise and fall of even a few feet will make a large strip which at high water is covered by the sea, and at low water remains dry. Where this strip consists of mud, no great change will be made in it, but where it is of harder material, such as granite or sandstone, the continual movement of the waves will wear the surface down to shingle, gravel, or sand. The latter, when it gets dry, is often piled up by the sea-breeze into a line of little hills called *sand-dunes,* just beyond the reach of the tide. Limestone, again, will be for the most part dissolved by the action of the water, and crumble away, leaving a *cliff* where the action of the water ceases. If the slope of the shore is steep and directly exposed to the force of the tidal wave, this will wear away the lower part of the rock against which it beats, and scoop it out, so gradually undermining it till the top falls over, and again leaves a sheer or even overhanging cliff, below which may often be seen great fragments of rock that have fallen from it, and are being slowly pounded to pieces by the waves. It need hardly be said that a wind blowing in the same direction greatly increases the destructive force of the tide.

§ 80. Another effect that may often be noticed is the formation of caves. This happens when part of the rock is of softer material than another, or when the water finds its way into a natural crack. In either case it will hollow out the rock at that point more than elsewhere, and so make a cave. It is this difference of rock that causes the *indentation,* as it is called, of the coast, and this is always greatest where there is much granite or other very hard rock near the coast and a steep slope of the shore; for the other rocks are eaten away round it, leaving the harder material standing out as headlands, or rocky islands. The west coasts of Ireland, Scotland, and Norway illustrate this very clearly.

Last of all we must notice the effect of the tide on the mouths of rivers. We have already seen that where it is

OCEAN CURRENTS



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Stanford's Geog! Estab!, London

not strong, the sediment from the river tends to collect at the mouth and form a delta. But where there is a strong tidal wave, it will eat away the shore round the river mouth, and form an *estuary*. Thus all the chief English rivers, such as the Thames, Severn and Humber, have estuaries, whereas not one forms a delta. You may wonder what becomes in this case of the sediment brought down by the river. For the most part it collects near the point to which the sea comes at low tide; for beyond that point the outgoing tide cannot carry it, and there it often forms a bank, known as a *bar*.

§ 81. Of the movements caused by winds, we have already mentioned one, that of waves. These vary in size, as we know, from the ripples almost always to be seen even on a calm day, to the great Atlantic 'rollers' sometimes forty or fifty feet in height, which are produced by a great storm.

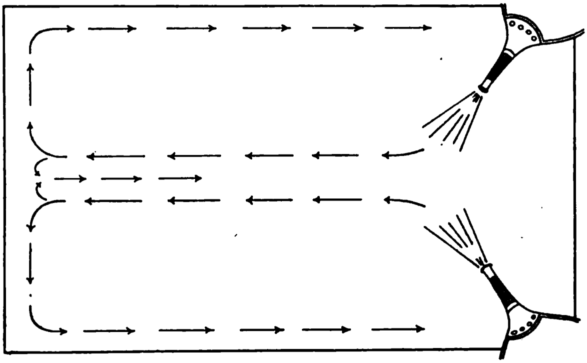


FIG. 43.—ILLUSTRATING OCEAN CURRENTS

More important, however, are the great *ocean currents*, and to understand how these come about, and where they flow, you must bear in mind what we learnt about the permanent winds in § 55. If you were to take a large tray or dish full of water, and blow from both sides with two pairs of bellows in a slanting direction, like that of the trade-winds, you would find that the water in the centre began to move in the direction marked by the arrows in fig. 43. And so in each of the great oceans near the equator there is a steady current flowing westward. Let us follow the result in each of them.

In the Pacific Ocean this *equatorial current*, as it is called—or rather these equatorial currents, for there are two running parallel with one another, north and south of the equator, with a sort of back-water in between—flow on till the resistance of the land (that is, the Philippine Islands and the coast of China) comes in the way of the northern one, and twists it round. It then flows along the coast of Japan, where it is known as the 'Kuro Sivo,' or 'black current,' and is bent still further round, so that with the help of the anti-trade-wind it is carried back towards the north-west coast of America. There a part of it is turned north again, but the main body of it curves southward along the coast of America, under the name of the 'Californian current,' and once more joins the north equatorial stream from which it started.

§ 82. Meanwhile the south equatorial current is stopped in the same way by the island of New Guinea and the eastern coast of Australia, though a little of it finds its way through the Torres Straits which divide the two. The remainder turns southward along the coast of Australia, where it is known as the New South Wales current, till it strikes the west of New Zealand, which twists it northward. This south equatorial current is not so easy to follow, because much of it is broken up and lost among the innumerable islands and coral reefs of the Southern Pacific. You must also notice a striking difference between it and the northern one which we followed first. If you look at your map you will see that the North Pacific is almost entirely shut in by land except on the south; and so the current is directed round till it comes back to the point from which it started, thus keeping up a circular movement, with a motionless expanse in the middle. But in the Southern Pacific you will notice that there is open sea to the south in which the warm equatorial current disappears. As, however, this is constantly taking water away from its starting point, more flows in to take its place, and this sets up a cold current from the Antarctic Sea, which creeps up the coast of South America and is known as the 'Peruvian current.'

Further, we saw in § 55 that towards the antarctic region there is a steady westerly wind, and this causes, or helps to cause, a continuous flow of water westwards, known as the 'Westerly Drift current.' Part of this strikes the coast of South America, and being turned northward, helps to start the Peruvian current; so that there is almost the same circular movement in the southern as in the northern ocean.

The same result is produced on a smaller scale in the Indian Ocean. The 'Mozambique' answers to the New South Wales current, and the 'West Australian' to the 'Peruvian current,' so that you can follow out for yourselves the reasons for these two in the South Indian Ocean. Those in the north are too slight to be of great importance, but they are the same in principle as those of the North Pacific.

§ 83. Last of all we come to the currents in the Atlantic, which are more marked, and, to ourselves at least, more important in their effect than any of those we have mentioned.

As in the Pacific, there are two equatorial streams flowing from the west coast of Africa; but the eastern corner of South America, ending in Cape Roque, just comes in the middle of the southern one, so that only half of this goes southward as the 'Brazil current,' while its place is taken along the west coast of Africa by the Benguela current. The other half of the southern equatorial current we must follow more closely. It travels along the northern coast of South America and so gets carried into the Gulf of Mexico. Here it is twisted round and passes through the Florida Straits into the Atlantic again. Meanwhile the north equatorial current, which has been bent northward by the long chain of the West Indies, has also reached the coast of Florida, and there joins the northern half of the south equatorial stream. You will now see why this is the most powerful of all the ocean currents, and as part of it comes through the Gulf of Mexico it has got the name of the 'Gulf Stream.' These two currents, then, now united as the Gulf Stream, flow along the coast of America, and then strike across the Atlantic as the Kuro Sivo does across the Pacific, helped on by the south-west anti-trade-wind. As it approaches the coast of Europe it divides once more; part turning south as the 'Canary current' and rejoining the original equatorial stream, the greater part flowing past the west coast of Ireland and Scotland. From there it travels across to the north-west coast of Norway, and can even be traced at Nova Zemlya and Spitzbergen, and far up into the arctic circle.

§ 84. There are still two ocean currents to be noticed, of a different kind to the circular ones we have traced in the Pacific and Atlantic oceans. They are caused by the fact that there is less evaporation in the Arctic Ocean than in either of the two oceans just mentioned, and so the water in it tends to reach a higher level. This leads to a constant stream of icy water pouring into the Pacific through the Bering Straits, and into the Atlantic from the passage between North America and Greenland. These flow along the eastern shores of Asia and North America till they are gradually lost in the warmer waters of either ocean.

To sum up what we have learned about these movements in the ocean. They are caused by the winds, especially the trade and anti-trade winds, and begin as westerly currents on both sides of the equator. Where the ocean is bounded by land they circle round its edge, leaving a still space in the middle; where the ocean is open to the antarctic seas, they lose themselves there, and a cold current sets in to take the place of the water driven from the eastern side near the equator, while the Westerly Drift current completes the circuit. These circuits take opposite directions in the northern and the southern hemisphere. Lastly, in each of the two northern oceans there is an 'arctic current' coming down the western shore to compensate for the evaporation that goes on in those oceans.

§ 85. It was said just now that these currents were caused by the winds, so you will not be surprised to learn that they are not very deep, but only what are called 'surface currents.' The Gulf Stream, for example, is only about 600 feet deep, that is roughly one twenty-fifth of the average depth of the ocean beneath it. Apart from these currents we have seen that the water becomes steadily colder as it gets deeper. We have already accounted for this to some extent by the fact that cold water is heavier than warm (§ 75), but it seems probable also that the greater part of the evaporation at the surface of the warmer oceans is made up for, not by water flowing in along the surface, but by colder and heavier water from the Arctic and Antarctic oceans, especially the latter, which travels slowly along the bed of the ocean to the tropics, where it gradually rises and in its turn is evaporated. So that as well as the surface currents, which on the whole flow most strongly away from the equator, there is a much slower but greater movement beneath the surface towards the equator.

§ 86. Before we leave the consideration of the sea, one other way must be mentioned in which land is sometimes formed beneath its surface, besides those already noticed in §§ 31 and 33. In the tropical parts of the oceans there is a little creature, known as the *coral polyp*, which fastens itself on to the rocks under the sea where it is shallow, and a colony of these polypes gradually build up what is called a *coral reef*, made of much the same material as limestone. Such a reef will go on growing till it reaches the surface of the water, and will then extend outwards in the open sea. Meanwhile the inner side, deprived of the food brought to it from the ocean, begins to decay, leaving a stretch of smooth water between the reef and the land. This is known as a *barrier reef*, and the water between it and the land is called a *lagoon*. The largest barrier reef on the globe stretches for over a thousand miles along the north-east coast of Australia.

Where a coral reef has grown up on the slopes of a mountain rising out of the bed of the ocean—as, for example, a volcano, of which there are many in the Pacific—it will grow up all round the sides till the surface is reached, forming what is called an *atoll*, or coral island—that is, a circle of land with a lagoon in the middle (fig. 44). Sometimes the top of the original mountain or volcano stands out in the middle of the lagoon as an island; in other cases this top did not quite reach the surface, or else it has gradually sunk below it, allowing the coral polyp to go on building higher. On the platform thus made, sand and other loose materials are thrown up by the waves, so that in time the land gets raised above the sea-level. Sometimes, too, the reef is bodily upheaved, as described in § 34, and stands high out of the water.

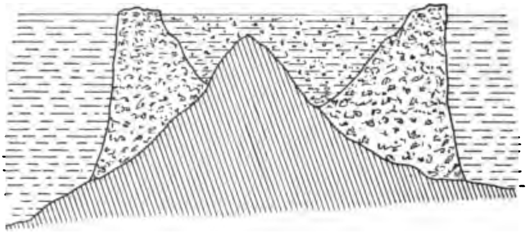


FIG. 44.—CORAL ATOLL

Questions on Chapter IX.

1. Mention any substances, other than pure water, to be found in the sea.

2. What do you know of the density of the ocean? How is it affected by the temperature?

3. Explain the difference between 'spring' and 'neap' tides, and how it arises.

4. Explain why places on the same line of longtitude have tides at different times.

5. Give an account of some of the effects produced by tides on the sea-shore.

6. What are the equatorial currents? Show how they arise.

7. Give some account of the currents in the Atlantic.

8. The sea by Vladivostok, on lat. 43° N., is always frozen in winter; at Vancouver, on the other side of the Pacific, about 5° further north, it is never frozen. How do you account for this?

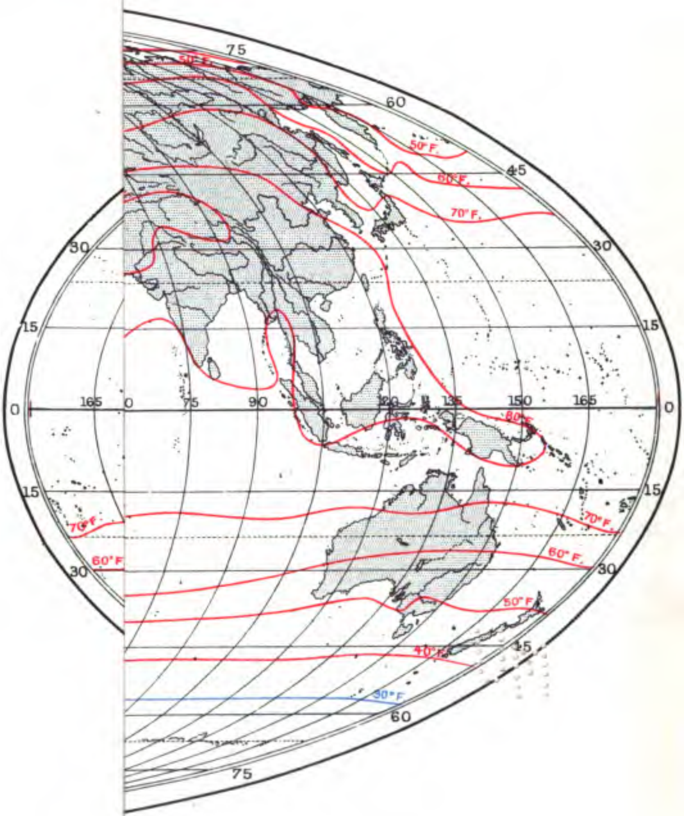
9. Explain the formation of an atoll.

CHAPTER X

CLIMATE

§ 87. WHAT we have learnt about the atmosphere and the sea will be a great help towards understanding the *climate* of different regions. Let us take, for example, an island lying on the east side of the Atlantic Ocean, between 50° and 60° north latitude, and see what can be inferred as to its climate. First, then, from § 15 we know that, as the sun at that latitude is never very high overhead, the island will not be very hot even in summer; that, in fact, it lies towards the north of the north temperate zone. Secondly, we learnt in § 56 that the sea is warmer in winter, and cooler in summer, than the land. The nearer, therefore, any region is to the sea, the less will be its heat in summer, and its cold in winter; for, by means of the recurring winds, the sea will warm it in winter and cool it in summer. So our island, being surrounded by the sea, will probably have what is called an *equable* climate, that is, no great extremes of heat and cold. Thirdly, we know that the Gulf Stream, which was described in § 83, must flow past its shores, and as this is a warm current from the tropical ocean, we shall expect the climate of the island to be warmer than the average temperature of the same latitude.

Finally, if we study the charts which showed the variations of atmospheric pressure, we shall find that the island lies just between the cyclonic area of the Atlantic in winter and the anticyclonic area of Eurasia; and as each of these shifts its position, it will come more under the influence of one or the other, so that there will be a constant change of wet and dry weather, with prevailing south-westerly and


75
50°F.
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50°F.
40°F.
45
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60
75

south-easterly winds. In summer we notice that it falls within the area of the Atlantic anticyclone, giving it a prevailing south-west wind; so that at all seasons the wind comes more often from the Atlantic than from the land on the south-east and east, and therefore contains a great deal of moisture; so we shall expect a considerable rainfall throughout the year.

The climate, then, of the island we have chosen may be described as temperate, equable, warm for its latitude, variable, and having a considerable rainfall fairly distributed throughout the year. You have probably already recognised it as our own island of Great Britain, and will agree that the description we have given of its climate is on the whole correct.

§ 88. If, however, we know something of the 'build' or configuration of the island, we can find out still more about the climate. Suppose we know that it is mountainous on the west, and slopes gradually down towards the east, we may then be certain that the west will have a much greater rainfall than the east; for the high ground meeting the moist wind from the ocean will force it upwards, and cause the moisture to condense, after which the wind, as it passes over the country, will be much drier.

From this example of our own island you will see that there are five main causes of difference in climate; and the climate is, perhaps, the most important thing to know about any region, for on it depend, first, its fertility—that is, the amount of life it is able to support, both animal and vegetable; secondly, the nature of that life; and thirdly, to a great extent, the character of its inhabitants.

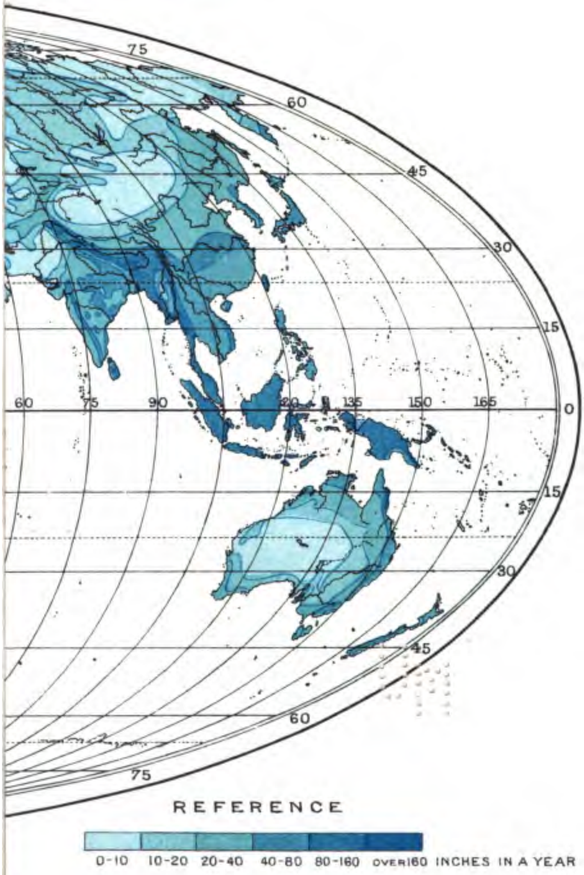
These five causes, in the order in which they were noticed, are as follows:

1. Latitude.
2. Nearness to, or distance from, the sea.
3. The surface current near the shores (if the region is not completely inland).
4. Prevailing winds.
5. Position of its highest ground.

§ 89. If you turn to the two charts given you, representing the lines along which the temperature is about the same, one for winter, the other for summer, and also the one showing the amount of rainfall in different places, you will be able to see from them how these five causes affect the climate in different regions.

You will see in both the charts giving the lines of equal temperature—called *isotherms*—that the regions in or near the tropics have, on the whole, the greatest heat, and those nearest the poles the least; and if the temperature only depended on latitude, the isotherms would all be parallel lines following those of latitude. As it is you will notice that the very hottest regions are always land surfaces, and occur in patches which rarely touch the sea coast. This illustrates our second cause. The same is true of the coldest regions, especially the one in the north-east of Eurasia, from which it grows steadily warmer as you go north towards the arctic seas. Again, if you mark how the lines curve upwards on the east side of the Atlantic and Pacific, and downwards on the western sides of these oceans, you will see the effect of the third cause—ocean currents. This is most remarkable in the case of the Gulf Stream, which gives to the north coast of Norway a winter temperature 50° higher than the coast of America in the same latitude, and makes the north-west coast of Scotland as warm in winter as Constantinople.

Turning now to the chart showing the difference of rainfall, you will notice that the heaviest always occurs at places on or near the coast, and the least on inland regions protected from the coast by mountains. This shows the importance of our fifth cause, and it is very clearly marked in the case of North America, where the moist anti-trade-wind strikes the Rocky Mountains, and gives them a very heavy rainfall, leaving the lower land to the north and east comparatively rainless. The same effect may be seen with the monsoon winds in eastern Eurasia. Australia, again, is almost rainless in the interior, because the highest ground is near the coast, and, further, the highest range of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90
120
135
150
165
REFERENCE
0-10
10-20
20-40
40-80
80-160
OVER 160
INCHES IN A YEAR

mountains faces the prevailing south-east trade-wind. Again the Sahara, Arabia, and Persia form a practically continuous desert, because all three are protected on the north, south, and east by mountains, while the wind rarely, if ever, blows on to the west coast of Africa against the prevailing north-east trade-wind. Lastly, you have only to compare the rainfall on this coast with that of Central America on the opposite side of the Atlantic at the same latitude, to see the difference made by the direction of the trade-winds, showing clearly the effect of our fourth cause, apart from the fifth.

Questions on Chapter X.

1. Give the chief causes of difference in climate, with some illustration of each from your charts of temperature and rainfall.

2. How would you describe the climate of Great Britain?

3. Account for the difference of winter temperature between the following places in the same latitude (about 62° N.):

Yakutsk, in eastern Siberia.
Aalesund, on the west coast of Norway.
Hudson Straits, on the north-east coast of North America.

4. In July, Eureka, on the west coast of North America, has a temperature of less than 60°; and Salt Lake City (about 600 miles to the east) has a temperature of over 90°. How is this to be accounted for?

5. Account for the very heavy rainfall on the north-west coast of North America, and the very slight rainfall on the north-west coast of South America. Also for the same difference between the centre of tropical South America and the centre of Australia.

C. ORGANIC GEOGRAPHY

CHAPTER XI

SOIL AND ITS PRODUCTS

§ 90. It was said just now that on climate depended the fertility of the land, and consequently its natural products, both animal and vegetable. This is mainly owing to its influence on *soil*, to which we must now turn our attention. In § 31 and elsewhere we learnt something of the action of the atmosphere, and of water, on the rocks forming the earth's crust; and we saw that this was first to break them up into finer and finer particles. It is that crumbled surface of the rocks which we call soil; so that, in the first instance, the nature of any soil will vary according to the kind of rock which lies beneath it. Thus, conglomerate and sandstone will break up into gravel and sand; limestone and chalk will become lime, or, if mixed with clay, marl; the chalk soils are usually distinguished by large quantities of rounded flint stones, made of silica, which has encrusted the relics of animals living at the sea bottom where it was originally formed. But in every case the layer of soil will be seen to differ in some way from the rock below, and can be distinguished at once by its darker colour. This is due to the decayed vegetation which has passed into it, and is known to geologists as *humus*.

§ 91. We shall find later that plants get the greater part of their nourishment from the mineral matter in the soil, dissolved by water and sucked up by the plant through its roots. The two important differences between various soils are therefore, first, the mineral matter contained in them, and second, how far they allow water to pass through them and dissolve that matter. As regards the first of these, it may be said that sand and gravel soils contain the fewest, and clay soils the most of the minerals required by plants, in a form in which they can be dissolved by water; but as all soils depend for their fertility mainly on the decay of former vegetation—that is, on the humus contained in them—this difference is of less importance than the second. Here again the clay and lime have an advantage over the sandy soils. The latter consist of hard loose grains, as you can tell for yourselves by picking up a handful of sand, and noticing that it does not hold together, or stick to your hand, as clay or chalk would. Through these loose grains the water trickles so fast that it has no time to dissolve much on its way, and what it does take up, it carries away with it to the less porous layers below. On the other hand, we have noticed before that clay is almost impervious to water (§ 63), which is thus able to dissolve the mineral matter needed by the plants, but cannot carry it from one part to another, and so diffuse the nourishment through the soil. Besides this it does not allow the warmth of the air to penetrate into the soil, and this prevents the decay of vegetable matter into humus. This is also true to a less extent of chalk and lime soils. It is not difficult to see, as a result of these comparisons, that the best soils will be a mixture of those formed from different kinds of rock; and it is always the farmer's aim, by means of what is called 'dressing' the soil, to make this mixture as perfect as possible.

Such a mixture will consist mainly of *sand,* so as to enable the water and also air to pass freely through, and warm the soil; next of *clay,* to prevent the water running through too quickly, and to provide the necessary minerals in solution; then a smaller quantity of *lime* must be present to provide the 'carbonates' needed by plants, and lastly there must be a fair proportion of *humus.*

§ 92. But there is another effect of water and atmosphere on the earth's crust, which has been frequently referred to under the name of 'denudation' (Chapter IV.). This was, we saw, to carry the crumbled rock, which we will now call the soil, from the higher to the lower ground; and it will have two great results on the soil. First, there will tend to be much less on high sloping ground than in valleys or level plains, and therefore we shall expect to find the most fertile regions in the latter, rather than on hillsides or in mountainous districts. Secondly, as the soil is carried down from many sides into the valleys, it will be more mixed, and therefore more fertile. Soil carried down in this way by water is called *alluvial*, and, under suitable conditions of climate, will always be more productive than any other; that is why the deltas of rivers are so fertile, for a fresh supply of alluvial soil is always being brought to them. So you see that denudation is constantly doing on a large scale what the farmer tries to do on a small scale, to add to and enrich the soil.

To sum up, then, what we have learned about soil: it consists of crumbled or 'decomposed' rock, and differs according to the kind of rock over which it is formed. It also differs from that rock in containing decayed vegetable matter known as humus, which gives it its dark colour. The fertility of the soil depends mainly on the extent to which the mineral matter in it can be dissolved by water; in this and other important respects the most fertile soil is a mixture of sand, clay and lime. Such a mixture will most commonly be found in river valleys where the soil has been carried down from different parts.

We must next consider the results of this fertility in the form of plant and animal life.

§ 93. The science which tells us about the wonderful structure and life of plants and animals is called *Physiology*; and it teaches us that plants, as well as animals, *breathe*, *feed*, and *reproduce* (*i.e.* form new plants of the same kind as the parent plant). We cannot go very far into the question of their structure, but we must learn something of those three 'functions,' as they are called, of plants. A plant may be said roughly to consist of three parts, *root*, *stem*, and *leaf*.

It is the last which chiefly corresponds with the lungs of an animal, and by means of which the plant breathes. If you examined a leaf through a microscope, you would find the surface, especially on the under side, full of little 'mouths.' Through these the air enters, and the oxygen required by the plant is absorbed. At the same time, under the influence of daylight, the carbon dioxide in the atmosphere (§ 43) is also absorbed by the plant, and combines with other substances in it to form the 'tissues,' of which the solid parts of it are made. So far, then, we have learnt that plants require air and light in order to grow, and have the power of extracting the carbon dioxide from the air when light is present. Now we found that too much carbon dioxide in the atmosphere was harmful to animals like ourselves (§ 43), and therefore plants do us a great service by removing it. That is why in the daytime it is a good thing to have plants in a room where people are sitting, for the latter, as we know, give out carbon dioxide when they breathe.

§ 94. Next as to feeding: you know that a plant draws up water through its roots, somewhat in the same way as a lump of sugar draws up the liquid from a spoon, and then extracts the minerals dissolved in it; so that *all the nourishment a plant gets from the soil must first be dissolved in water*: in other words a plant drinks, but it cannot eat. You will easily realise that in order to get enough food by this means, a plant must draw up a very great deal of water, and you may wonder what happens to it all. Well, it passes into the cells or minute compartments of the stalk and leaves, and is evaporated from these into the air. It has been calculated that as much as a quart of water may pass through a sunflower in a hot summer day, and that in the same time an oak tree will sometimes draw up, and lose by evaporation, twenty-five gallons of water. So then all plants may be regarded as living pumps, drawing water from the soil, removing the matter dissolved in that water, and sending it into the air as water vapour. From this we learn that warmth and moisture are necessary to the growth of plants, as well as air and light: for if there is not enough warmth to evaporate the water, its 'circulation' through the plant will be stopped. That is why many plants die, and others stop growing in winter. Again, if the warmth is so great as to evaporate the water too quickly to be replaced from the roots, the plant will become 'limp' because its cells are no longer full of water, and soon it will die. In dry tropical regions, where the amount of moisture available is small, plant leaves are very often hard and 'glazed' so as to protect them from the great heat, and check the evaporation. We shall now be able, with the help of our rainfall chart, to form a fairly correct idea of what parts of the earth have a luxuriant vegetation, and in what parts it is scanty. Those which are either very cold, such as the extreme north of Siberia, or very dry, as the Sahara, will be barren; those which are both warm and moist, such as the East and West Indies, will be just the reverse.

§ 95. We must now see what these substances are, or at least the principal ones, which plants draw up in solution from the soil. The most important is *nitrogen,* which comes partly from humus, in the form of ammonia; partly from the nitric acid and ammonia washed down from the atmosphere by rain (§ 43); and sometimes from compounds of nitrogen in the soil, known as *nitrates.* Besides nitrogen, *sulphur* and *phosphorus* are also found in all plants. Several other elements are necessary to their growth, though a plant may exist without them; of these the chief are *potassium, magnesium,* and *iron.*

Now you know that the greater part of the soil does not melt in water; in fact, only a very small proportion of it is 'soluble,' as it is called, and able therefore to be used as plant food. Even in a fertile soil more than three-fourths of the earth consists of quite insoluble matter, and all the substances together, except iron, which we mentioned just now as being the most important, only make up about one-fiftieth of the whole.

§ 96. It is important to bear in mind what we have learned of 'plant foods,' as otherwise it would often be difficult to understand why two places with much the same climate have quite different plants, and why the same plants are often found in very different climates. For some soils are rich in certain kinds of plant food and deficient in others, and so better suited to those plants which require more of the particular materials in which the soil abounds than of those which it lacks. A chalk soil, for example, favours the growth of beech trees, a sandy soil that of pines, and a clay soil, of oaks. The same principle explains why farmers grow different crops on their land in succession. Clover roots store up nitrogen ready for wheat, which in turn exhausts much of the silica, and is followed by roots such as turnips and mangolds which require very little silica; while the nitrogen and potash (a compound of potassium) which are stored up in their leaves go back to the soil ready for a crop of barley, which requires to have these near the surface, as it has no deep roots.

You must regard a plant, then, not only as a living thing which breathes, or as a pump which draws up and evaporates water, but also as a chemical laboratory, where various substances are continually being changed into other forms, gases into liquids and liquids into solids; though you would need to know much of the science of chemistry as well as of physiology to be able to understand more about these changes, and the substances produced by them.

§ 97. Last, we come to the third of the 'functions' mentioned in § 93—that of reproduction, or the making of *seeds*. However different the forms may be in which these are found, as, for example, in a bean pod, an ear of wheat, and a plum, they are all alike in this, that when they are separated from the parent plant, they can, under favourable conditions, grow into plants like the one from which they came. None of these 'fruits' we have taken as examples is actually a seed, but each contains one or more seeds. Again, only a very small part even of the seed itself is taken up by the beginnings, or *embryo*, of the new plant. What, then, is the rest? It serves various purposes, but in the main it is a little store of food ready for the seedling to draw upon as soon as it begins to grow.

Let us look carefully at each of these fruits in order to understand this better. When we open the bean pod, a number of beans are found all fastened to one edge of the pod in a line. We will take one off and peal away the coat. Inside we find two halves only joined together by a little hinge close to the edge. This hinge is the young bean plant. If we take another of the beans and put it on a tile in some water in a warm place, it will absorb some of the water and swell. Soon the coat will burst, and after a time the little hinge will be found to have grown. One end will have developed something of the nature of leaves curled up together, the other end will have sent out little fibres like hairs. No matter how the bean is placed, if you plant it in earth, the first of these ends will always try to shoot upwards, and the second, downwards. Meanwhile the two halves which formed the greater part of the seed have shrunk. They contained nourishment which the plantlet has sucked in to enable it to start growing.

§ 98. Now let us take the ear of wheat. Here, the seeds are arranged round a central spike in several columns, each seed having a covering called the 'husk.' Inside this is the grain, having at one side a little dark patch, known by millers as the 'chit.' This is the embryo wheat plant. If the grain is treated in the same way as the bean, this embryo will shoot out like the other into a leaf-stalk at one end, and rootlets at the other. The rest of the grain, inside its coat, is made up of the white powder which falls out when the grain is ground, and we call flour. This will be used up by our little wheat plant in the first stages of its growth; but in this case the store of food is separate from the embyro, not part of it, as in the case of the bean.

In the plum, we find a sweet, juicy pulp, covered by a skin, and inside this the stone. These all correspond to the bean pod. Inside these, again, is the 'kernel,' formed on the same principle as the bean. So you see that even where the fruit of a plant is used by animals for food, it is not necessarily the actual seed that is eaten.

§ 99. The question then arises: What does the store of food in the seed consist of? It differs very much in different plants, but the various forms may be grouped under two main heads. First, substances made of carbon, hydrogen, and oxygen, known as *carbohydrates*. The most common form in which these occur is *starch*, and this makes up the greater part of all grains. But carbohydrates also take the form of oils, such as that got from linseed, olives, and cocoanuts (copra), and also of fats, of which maize has a large proportion. The second group consists of substances made of carbon, hydrogen, and oxygen, with the addition of nitrogen. These are called *hydrocarbons*, which occur chiefly in the form of *proteids*; and these are a necessary part of all living beings. The form in which these occur in seed grains is called *gluten*.

§ 100. Finally, you might wonder why seeds do not begin to grow, or *germinate*, as it is called, as soon as they are formed. You will remember that we had to put our bean and our wheat grain in a warm place, where water could reach them, when we wanted them to sprout; so, then, a special degree of warmth and moisture are necessary. When it is very wet at harvest time, the grain does sometimes germinate before it has been separated from the parent plant; but seeds are, as a rule, so constructed, that in our climate, at least, germination does not begin till the following spring, after they are ripened.

It would be difficult, if not impossible, to explain exactly what takes place when the seed does germinate; the important thing is to remember that the warmth and moisture enable the carbohydrates, especially starch, to dissolve into something more of the nature of sugar, which can be absorbed by the embryo; and the proteids to take a liquid form as *amides*, and so be likewise absorbed. The question of temperature is important in helping us to understand why certain plants can only be cultivated within certain isothermal lines (§ 89). Wheat, for example, cannot germinate at a lower temperature than 41°, and does so most easily at 89°. Maize requires at least 49°, and germinates best at 93°. This means that, as a rule, maize will not begin to grow till later in the spring than wheat, in the same place, and so may not have time enough to ripen before winter begins again, while the wheat, which was able to start sooner, will be able to do so.

The following table will help you to remember what has been said about plant foods :

Carbon Hydrogen Oxygen	make *Carbohydrates* in form of	Starch Oil Fat

changed by germination into sugar.

Carbohydrates and Nitrogen	make *Hydrocarbons* in form of	Proteids Gluten

changed by germination into amides.

§ 101. We have gone more fully into this last function of plants, because it is mainly the fruit, if not actually the seed of plants, that is cultivated by man for his food; and it is with those plants that he cultivates that we are chiefly concerned. It is true that many plants are cultivated not for their fruit at all, as, for example, the potato, of which we eat the swollen underground stem, or the swollen root-stalk of the carrot, the leaves of the cabbage, the leaf-stalk of celery and rhubarb, and so on ; but in the case of all '*staple' foods*—that is, of plants used as a chief article of food by man and not merely as a relish—it is the reserve store of nourishment intended for the support of the young plants which he takes for his own use. And before we leave this part of our subject a word of warning is needed. You must not think that we know why all these wonderful changes take place ; how it is that a plant is able to build up what it takes from the air and the soil into the manifold forms we see round us, or to produce another plant like itself. All that we can do is to learn a little about what actually does happen, without attempting to explain in any way why it happens.

§ 102. You are naturally accustomed to thinking of plants and animals as very different things, but in reality they are more alike than you might suppose. Both are made of practically the same materials, taking the form of minute partitions called cells, which contain a mysterious, constantly changing substance called *protoplasm.* It is this constant change of the protoplasm which preserves in both what we call 'life,' and in both the change is kept up by the two processes of breathing and feeding. It is the latter that we have mainly to deal with in the case of animals.

Now animals cannot get their nourishment direct from the earth, as plants do; but, unlike plants, they have for the most part the power of taking their food in a solid form; consequently they get the material which the plant has extracted from the soil by eating the plant, or some part of it. Others again find it more convenient to eat other animals, which in their turn have got their food from plants, and so on, like 'The house that Jack built'; but in the long run it still remains true, that animals live by feeding on plants. Those that do so directly are called '*herbivorous*'; those that live on other animals, '*carnivorous.*' Man is no exception to the other animals; but he can live either on plants, as the greater part of the people of India do, or on animals, as the Esquimaux do, who live almost entirely on fish, and more usually takes both, as we do ourselves. He is therefore called an *omnivorous* animal.

Questions on Chapter XI.

1. Explain what is meant by soil.
2. Of what would the most fertile soil consist, and where would you be most likely to find such a soil?
3. Describe how a plant feeds itself.
4. In what parts of the globe would you expect to find the most luxuriant vegetation, and why?
5. Mention the most important elements in plant foods.
6. Give some examples of the influence of plant foods on vegetation.

7. What is a seed, and of what is it mainly composed?

8. Describe as clearly as you can what happens when a seed germinates.

9. Mention some ways in which plants and animals are alike, and some in which they differ.

10. What are meant by the terms: humus, alluvial soil, nitrates, embryo, gluten, staple food, protoplasm, omnivorous?

CHAPTER XII

RELATION OF MAN TO NATURAL PRODUCTS

§ 103. No doubt our earliest forefathers lived to a great extent, like other animals, on the plants which grew within their reach and were found to be good for food; and in tropical regions enough of these would easily be found, chiefly in the form of fruits, such as the cocoa-nut and bread-fruit. To these might be added birds' eggs, honey, and if near to the sea-shore, shell-fish, &c. But from the first man distinguished himself among rival creatures by his skill in hunting and killing other animals. The lowest savages are still wonderfully clever in this art, which civilised peoples have for the most part lost; though the old instinct still shows itself in the love of what we call 'sport.' Now man is by nature inferior to many, if not most, animals in such important qualities as strength, swiftness, endurance, and power of concealment. How, then, did he get the better of them? It was through his superior intelligence, or we might say, cunning. He learned how to set pitfalls and snares for them, and, more important still, how to make and use weapons. Later, he even succeeded in taming dogs and birds sufficiently for them to help him in securing his game.

Another thing which seems from the earliest times to have marked him off from all other animals, is the art of making and keeping fire. Besides being a defence—for all wild animals are afraid of fire—this enabled him to cook his food, and so make it more digestible and wholesome.

§ 104. Many savage races, such as the natives of Australia and many of the islands in the Pacific, live even now on wild fruits and plants, and on the animals they can catch by hunting, snaring, and fishing. But a great advance was made when other races learned the art of taming and rearing certain useful animals. The great plains of natural grass land in the centre of Eurasia were specially suitable for keeping large flocks of sheep and herds of cattle, and gave plenty of room for moving them from place to place when the pastures at one spot were eaten away. This necessity for constant moving prevented men from building permanent houses or towns, but for protection they formed themselves into companies or tribes, and are known as '*nomadic*' or wandering people. We have familiar examples of this state of life in the account of Abraham and Lot in our Bible; and the Arabs, and many other races of central Eurasia, live in much the same fashion even now.

§ 105. Let us see what mankind gained by taming, or 'domesticating,' these animals. First, when he wanted meat he could choose a suitable animal to kill without having to hunt for it—an advantage well illustrated by the story of Jacob and Esau. Next, as well as the flesh, he could get leather and skins for clothing and other purposes. Thirdly, without killing any of his flocks or herds, he could get every year wool for clothing, and a more or less constant supply of milk (that is, of the store of nourishment provided by the cows for their young, as we saw the seed was for the young plant). Further, by many generations of careful breeding, his cows came to produce more milk, and to give it all the year round, and the sheep came to have better fleeces; and this process of improving the domestic animals in those qualities which are useful to mankind goes on still. Lastly, by training horses and donkeys to carry him on their backs, and oxen to pull loads for him, he was able to get from place to place more easily, and to take things with him which he could not have carried himself.

§ 106. Just as man did with certain animals, he did also with certain plants. He found that the seeds of some grasses in particular made an excellent food for him, especially in warm climates, where too much meat is apt to be injurious; and as with the milk and fleeces of his animals, so with the seeds of these grasses, he set to work to improve them, and make them give more nourishment: and from them we have got various kinds of *grain*, wheat, maize, rice, &c., which form the staple food of the great majority of human beings.

Now just as the grassy uplands and plains of central Eurasia were best suited to the nomadic peoples, so the fertile river valleys and deltas were the natural resort of the *agricultural peoples*; and whereas the nomadic people were obliged to roam from place to place, the agricultural ones naturally kept to their good cultivated land, and were able to build houses and cities; also they had a common interest in defending their rich land against invaders from outside, and so tended to unite in great 'states,' such as we know to have existed many thousands of years ago in the valleys of the Nile, and the Euphrates, and probably also in those of the Hoang-ho in China and the Ganges in India. It was in these states that men first became really *civilised* as we understand the word now—that is, they had most of the arts we have now, though not the same appliances, and on the whole they thought much as we do. This we know from the records they have left us in Egypt and Persia.

§ 107. We must now glance at another very important element in man's growth towards civilisation. The earliest *tools* or *weapons* of which we have any trace are of wood, horn, or stone; and as the last was the most durable, and for most purposes, especially cutting, the most serviceable, the earliest age of man's history has sometimes been called the *stone age*.

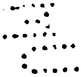
Later, the discovery was made that certain metals—bronze, and later on, iron—could be melted by fire and made into much better tools and weapons than stone; and as better ways of making and using these were discovered, more and more perfect instruments, whether for warlike or peaceful purposes, came into use; and finally, with the discovery of the power of coal for heating, and steam for supplying force, have come our modern railways, and factories for the making of almost every imaginable thing.

So that for almost everything that we need each hour of our lives, we depend, directly or indirectly, on the *supplies of coal and iron.*

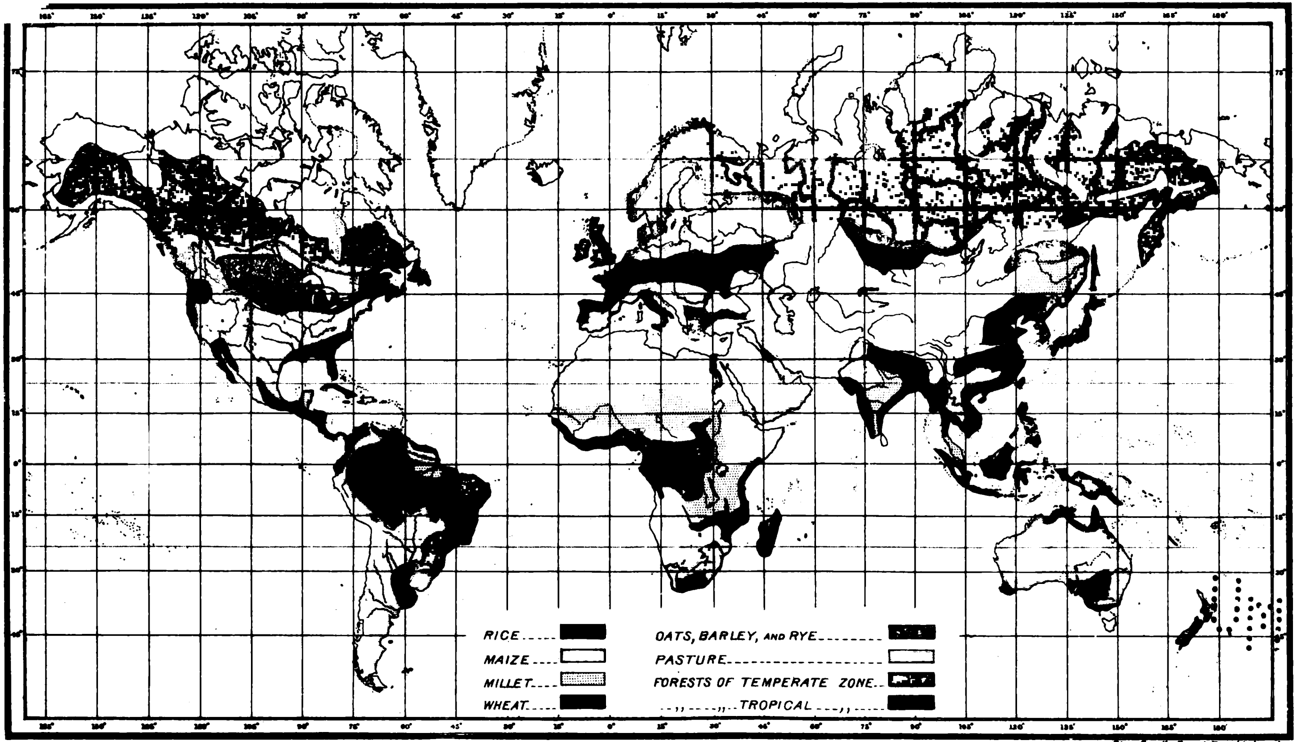
Our next task will be to find out where all these things required by man for his food and use are best to be found.

Questions on Chapter XII.

1. In what ways did the early savages show themselves superior to the other animals?
2. What advantages had the nomadic people over these savages?
3. What are the chief differences between a nomadic and an agricultural people?
4. Give some idea of the change in human life caused by the discovery of the art of smelting.



STAPLE PRODUCTS.



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CHAPTER XIII

STAPLE PRODUCTS CULTIVATED BY MAN

§ 108. We learnt that the greater part of mankind lives chiefly on some kind of grain or *cereal,* and since their chief occupation, therefore, is to cultivate these cereals as food for themselves and their fellows, we must first try to find out what parts of the earth are best suited for each kind. Next in importance to the cereals come the domestic animals, especially cattle and sheep, and we must find out where these can best be raised. The accompanying chart will help you to understand the 'distribution' of each of these products, and for completeness, the great forest regions have also been added; but of course you must not imagine that only the one thing represented by a particular colour is produced in each region. The colouring is only intended to show you where each staple product is most abundant.

We will now take each of the cereals, and the other products just mentioned in detail.

§ 109. One of the cereals which supports a very great number of human beings is *rice.* Like all the others, it is a cultivated grass; it requires a very warm climate, much moisture, and a rich soil, so we shall naturally look for it in tropical or subtropical regions, where there is a heavy rainfall (see plate VI.), and especially in the deltas of rivers (§ 92) and the valleys of those which regularly overflow their banks, or can be made to water their valleys by irrigation. The rivers which most strikingly fulfil these conditions are the Irrawady, the Yang-tse-kiang, the Ganges and the Nile; while other districts with rich soil and heavy rainfall are Southern

China, the East Indies, and the south-east corner of the United States.

Besides being used for food, rice is one of the chief sources from which we get starch. But though rich in this, it is correspondingly lacking in gluten, and is consequently less nourishing than other kinds of grain (§ 98).

§ 110. *Maize* has many varieties, and it is the largest of all the cereals, sometimes growing to a height of twelve feet. The seeds when ripe are large and hard, with a smooth, gold-coloured skin, and form clusters called 'cobs.' Maize does not require so much moisture as rice, but nearly as much heat, while the least touch of frost kills it; so we shall look for it in the open plains of subtropical or warm temperate regions, where there is good soil. The region which best satisfies these conditions is the centre of the eastern half of the United States, and here about four-fifths of the whole supply[1] of the world is raised; but it is largely grown also in South Africa, where it forms one of the staple foods of the Kaffirs, under the name of 'mealies.' It is also generally found in all the southern countries of Europe, in India, and the Argentine Republic in South America.

When ground, the flour can be made into cakes, or, if mixed with rye or wheat, into a coarse bread; by removing the gluten, 'corn flour' is made from it, and like rice it is a large source of our supply of starch. The grain contains a considerable proportion of fat (§ 99), and is very nourishing, and so is largely used to fatten cattle and poultry. In America the whole cobs are often cooked before they ripen as a vegetable, and the leaves are used for fodder. Where wood is scarce it is sometimes even grown for fuel!

§ 111. The commonest grain of the tropics is *millet*. There are many varieties of it, differing very much from one another, and flourishing in such different climates as the swamps of the Amazon and the borders of the Sahara. It is the chief food of the natives of India, and also throughout the larger part of Africa; and it is widely grown in Australia and Northern China. Like maize it does not make a good bread-flour, but is eaten in cakes, and is very nourishing.

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[1] When the 'supply' of anything is spoken of, it means the amount of it produced over and above what is used up on the spot by those engaged in producing it.

Wheat is the staple grain of the peoples of Western Europe and North America; and like millet it is very 'adaptable,' suiting itself to widely different conditions of climate and soil. It flourishes best, however, in a warm temperate region, in a heavy soil, such as clay or loam, and does not require much moisture. Three large regions exactly meet these requirements: the central 'basin' of North America, lying partly in the United States and partly in Canada; the south-west of Russia, where there is a very rich 'black' soil; and the valley of the Plate River in the Argentine Republic. But it is also grown largely in all European countries except Norway and Sweden, as well as throughout the Turkish Empire, Persia and India.

Wheat is eaten almost always in the form of bread, except in Italy, where much is made into 'macaroni.' It is rich in gluten, though, unlike maize, it contains little fat. It is to make up this defect that we take butter with it.

§ 112. The cereals of the north temperate zone are oats, barley, and *rye*. The first two are found under much the same conditions as wheat, but do not require so much heat to ripen them. Oats are largely used to feed horses, and barley chiefly for brewing beer, and also for 'distilling' whisky. Rye needs even less warmth than the other two, and will flourish on poorer soil; it may be found as far north as the arctic circle, and in places even beyond it. Hence it is the staple food of the northern countries of Europe, and throughout the northern part of the great Eurasian plain, which has for the most part a poor, sandy soil.

Besides these various cereals, large quantities of different kinds of bean plants, called '*leguminous*' *or* '*pulse*' crops, are grown and eaten in different parts of the world. Peas, haricots, and horse beans are some of the kinds most familiar to us, but there are many others.

§ 113. Turning next to *pastures*, we must distinguish carefully between those suited to cattle and those best adapted for sheep. Both these animals feed naturally on grass; but while cattle like the rich, thick grasses which they can tear up with their strong blunt teeth, sheep prefer a short fine grass, which they cut almost like a mowing machine, with their smaller and sharper ones. Also, while cattle are content to browse in the same spot as long as there is enough for them to eat, sheep require a constant change of pasture, and so they do best in wide open stretches of country.

Now the thick sweet grasses, such as our own 'meadow grass,' grow best in low-lying, or well-watered plains, while the finer 'turf' grasses are found where there is little moisture, or on hillsides where the soil is thin. Thus the grass slopes all along the eastern side of Australia are wonderfully adapted to sheep farming; so are the hillsides of New Zealand; the mountainous and little-watered regions of Persia and Arabia, and the dry plain to the north of them; the rolling 'veldt' of South Africa; and the eastern slopes of the lower Andes, and of the Rocky Mountains. Sheep are, of course, reared mainly for their fleeces, to make woollen fabrics.

Cattle, on the other hand, thrive better in the well-watered plains of North America, especially in the south-west of the United States and in Mexico, in the Plate Valley of the Argentine, already mentioned for its wheat-growing, and throughout Western Europe. There are also large quantities of cattle in India, but the natives do not eat them, and only use their milk and hides. They also serve them as draught animals.

§ 114. The *horse* is the animal mainly used in Western Europe, in North and South America, and in Australia, for drawing and carrying loads, and there are parts of each of these regions well adapted for rearing them: notably Ireland, Hungary, and Southern Russia, in Europe; Mexico and Bolivia in the two Americas. The *donkey*, being hardier, is found in many places where horses cannot thrive, especially in Africa. But throughout the greater part of Eurasia, *oxen* are chiefly used for draught purposes, while in the waterless regions of Africa and Asia the *camel* has to be employed, owing to the great distances it can travel without drinking. In India the *elephant* is also used.

§ 115. We can see from our chart the vast stretches on the globe covered by *forests*; and only those are coloured as such which have little or no cultivated land as well, so that the actual area of forest is very much greater. For example, nearly half of Sweden and eastern Germany are occupied by forest, though nearly all this region on our chart is marked as producing rye, barley, and oats. In the same way only an imperfect idea is given of the great forests of North America. We should probably not be far wrong if we regarded the greater part of the temperate zone, and all of the tropics where there is an abundant rainfall, as naturally covered with forest, and the cultivated land as 'clearings' gradually made in it by man. But though they have to a great extent given way before agriculture, forests are very important, not only for supplying timber, but also for preventing too rapid evaporation of moisture (§ 47) and so preserving it in the ground. Wherever forests are cleared away it is found that the rivers get smaller, and the land tends to become parched and barren.

These natural forests differ very much according to their latitude and height above sea-level; and we may broadly divide them into three classes.

(1) *Tropical forests*, usually of very large 'evergreen' trees, with a thick, often impenetrable, undergrowth of smaller trees, bushes, and creepers. We shall find these wherever there is a very heavy rainfall in any tropical region (§ 94).

(2) *Deciduous forests*—that is, of trees which shed their leaves in winter; such as those we have for the most part in our own country. These trees are chiefly found in the warm temperate zones.

(3) *Coniferous forests*—that is, of different species of pines and firs, the fruits of which take the form of 'cones.'

These are mainly found in the colder temperate regions, and stretch up to the arctic zone.

§ 116. From the tropical forests we get *teak* and *greenheart,* both valuable on account of their toughness and power of withstanding the action of water. *Mahogany,* from Central America, is much used for making furniture, as it is durable, and takes a beautiful polish. Some trees are useful for other purposes than as timber: from the sap of one we get *india-rubber*; from the bark of another the valuable drug *quinine*; from others, again, such *spices* as cinnamon and nutmeg. Among the trees of the tropical zone must also be reckoned the different *palms* which produce dates, cocoa-nuts and sago, as well as vegetable oils. Also the *bamboo* cane, which is useful for making rods and poles on account of its strength and lightness. Two other valuable trees occupy most of the wooded regions of Australia, the *eucalyptus* and *acacia.*

Most of the deciduous trees make serviceable timber, especially the *oak* and *elm,* those of English growth being among the best; the *chestnut* and *walnut,* in Central and Southern Europe; and the *maple,* which flourishes in North America.

§ 117. But it is on the pine forests of the north temperate zone that we chiefly depend for the timber in ordinary use among us. They contain many varieties of pine and fir, among the commonest being the 'Scotch pine,' from which comes our 'red deal'; the 'yellow pine' of Canada, and the 'white pine,' often called the Weymouth pine, and specially used for ship masts and spars. The Californian pine is a much larger tree, and so is the Kauri pine of Australia; both make good timber.

Now if our pine logs had to be carried many hundreds of miles by road or rail they would be very costly, so that at present we get our supplies almost entirely from places with easy reach of water. Thus the wood from the forests round the Baltic is floated down the rivers to the coast, and then shipped over to this and other countries. Its journey wn the rivers has the further advantage of 'seasoning' it—that is, removing the sap, and making it ready for use; and often the water-power is also used for saw-mills, to cut it into 'baulks' or even planks, before it is taken across the ocean. Vast quantities of timber come to us in the same way from the forests of North America. The logs are floated down the great rivers, especially the St. Lawrence and the Missouri, in gigantic rafts to their mouths, where the rafts are broken up, and loaded on ships, their whole journey sometimes occupying several years.

The different pines and firs also give other valuable products, such as turpentine and resin.

Questions on Chapter XIII.

1. Mention the chief cereals, and some of the regions where each is most commonly found.
2. Give some of the uses of maize.
3. What parts of the earth are best suited to sheep pasture, and why?
4. What is a draught animal? Mention any that are used as such in different regions.
5. What use have forests, besides providing timber?
6. Give the different kinds of forests, and some of the more important trees in each kind.
7. Where does most of our timber come from, and how is it brought?

CHAPTER XIV

OTHER NATURAL PRODUCTS USEFUL TO MAN

§ 118. Our next chart marks some of the more important vegetable products used for making *fabrics*—that is, woven materials, such as cotton, silk, and linen; also those cultivated for making drinks, such as tea, coffee, wine, and beer; and a few others—cane and beetroot for making sugar, tobacco, and hemp for making ropes, string, and sacking.

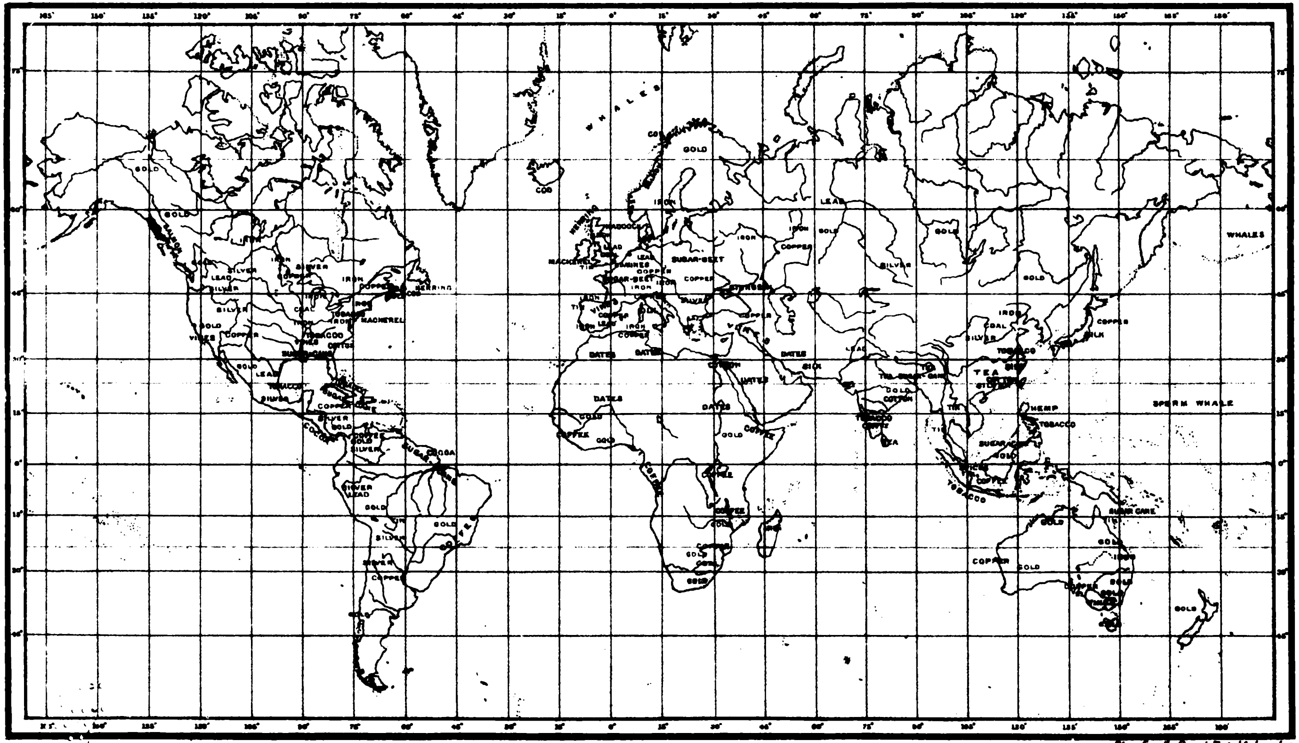
But we saw also that the more civilised races are dependent for their manufactures on coal and iron, and, to a lesser extent, on other minerals; we must therefore learn where these, too, are to be found. The principal sources of our supplies have been marked in red on the chart.

Lastly we shall glance at some of the chief *fisheries*.

§ 119. The chief fabric used by mankind is cotton, made from the fluffy hairs which grow on the seeds of the *cotton plant*. This plant well illustrates what was said in § 96; for while it requires much the same conditions of climate as rice, special peculiarities of soil are necessary to produce a good quality of fibre; so that, for example, West Indian cotton is much more valuable for manufacture than East Indian. About three-fourths of the supply used for manufacture in Europe comes from the rice-producing district of the United States; the remainder chiefly from Egypt, India, and Southern China.

Silk is made from the cocoon of the *silkworm*, a caterpillar that feeds on the mulberry tree. It is reared in

OTHER NATURAL PRODUCTS.



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various parts of Southern Eurasia, especially Italy and China, and also in Japan.

Linen is made from the stalk of the *flax plant*, which is very widely distributed, and largely cultivated in Northern Russia and Ireland.

§ 120. The drinks made from vegetable products may be divided into two classes. First, those made by *infusion*—that is, by pouring boiling water on the part of the plant used, and so dissolving the invigorating drugs contained in it. Second, those made by *fermentation*.

Tea, an infusion from the leaves of the tea plant, is probably drunk by a larger number of people than any other prepared liquid. Yet the tea plant is not at all widely distributed, being practically limited to three regions : Southern China, Ceylon, and the southern slopes of the Himalaya. But various other plants are prepared and used in the same way, in other parts of the earth. Of these the most important is the Yerba, or 'Paraguay tea,' used in South America.

Coffee is made from a berry prepared in much the same way as the tea leaf, and containing the same invigorating drugs. It is far more widely distributed than tea, being found over a large part of Africa, in Arabia, and both the East and West Indies. But the great bulk of the coffee used in Europe comes from Brazil.

Cocoa is less stimulating, but much more nourishing, than either tea or coffee, and is eaten in the form of chocolate, as well as drunk. It is only found along the eastern tropical coasts of America—that is to say in Central America, and the north coast of South America.

§ 121. Plants of the most varied description are used in different parts of the earth for the making of fermented liquors; for example, the banana, the date and other palms, and all the cereals. By the Tartars even milk is used for this purpose. It might be wondered how such different materials all come to produce intoxicating drinks; but fermentation is really a natural process, by which the store of solid food contained in plants is made soluble, and so available for their use (§ 100). The first step in this process is, as we saw, to change the 'starchy' matter (*i.e.* the carbohydrates, § 99) into a kind of sugar. If, however, the fermentation continues, this sugar will finally be turned into two gases, carbon dioxide, and *alcohol*. The first of these is, you will remember, the gas from which the starchy matter in plants was originally formed (§ 93); it is the second which gives fermented liquors their intoxicating effect. In making *beer* from any kind of grain, the fermentation of the grain is checked before much alcohol has been formed; but in the manufacture of *spirits*, such as whisky or brandy, it is allowed to continue, and the alcohol is then collected by what is called 'distilling,' and brought into a liquid state.

Wine is made from the natural sugar contained in ripe fruits, but as a rule we mean by the word the fermented juice of grapes. The *vine*, of which they are the fruit, is found in many parts of Southern Eurasia, especially Persia and Asia Minor, but for centuries it has been most carefully cultivated in Central and Southern Europe. It seems to develop the best flavour in soil of volcanic origin (§ 38), and requires great skill in its management. Vines are now reared in California and in Victoria (South-Eastern Australia); but the wines made in these regions are not yet equal to those of the best vineyards in Spain, France, Germany, and Italy. In Persia and Asia Minor the grapes are largely dried and exported as raisins.

§ 122. Sugar is partly got from the sap of the *sugar-cane*, a plant which requires great heat, and a very rich, moist soil. Until early in the last century 'cane sugar' was the only kind in general use, and it was then the staple product of the West Indies, and of the south-east of the United States, as well as of a large part of the East Indies. It was then found that the natural sugar of the *beetroot*, if grown under favourable conditions, could be made into a good substitute for cane sugar. For this it requires a good soil, and a long period of sunshine; and this is best obtained along the southern edge of the northern plain of Western Eurasia; so that the region of its most successful cultivation is divided among France, Germany, Austria, and Russia. In

North America the *maple* is much used as a source of sugar.

But we saw in the last section that all the natural starches could be changed into sugar by fermentation, and a great quantity is made in this way from different kinds of grain, especially rice and maize. Finally, it will help to give you an idea of the wonderful results of chemical changes, to learn that sugar can now be manufactured even from such unpromising materials as rags, paper, and sawdust! For all these contain vegetable carbohydrates, which can be made to ferment.

§ 123. *Tobacco* requires for its successful cultivation a specially rich soil; and though it is grown in many parts of the world, in only a few is the leaf produced of much value. These are notably: Cuba in the West Indies, Virginia in the United States, the Philippine Islands, Java and Sumatra in the East Indies, and the south of the Indian peninsula.

Hemp is found under very varied conditions of climate, as will be seen from the fact that two of the regions where it is most cultivated are the Philippine Islands and Central Russia.

§ 124. The important minerals will be more fully dealt with in the accounts given of separate regions; and it should be remembered that many almost certainly exist in various parts of the earth where at present they are not used, or perhaps even known of. We shall here only touch on the character of some, and give the main sources of our supplies of them.

Coal is of all the most important, for we have seen that all our modern industries are dependent on it. Its origin takes us back many ages, to a time when the north temperate zone was very much warmer than it is now, and when far more of it was covered by the sea (§ 34). Along the shores of this in many places grew dense 'jungles,' or marshy tropical forests, consisting for the most part of varieties of tree-fern. These shed their seed 'spores,' and also their bark, so rapidly that layers of them were covered over, before the action of the water and air had time to 'decompose' them. Now, as the land rose and fell, these layers alternately sank beneath the sea, and were covered with other strata, such as were described in Chapter IV.; and came up again, so that fresh layers of vegetable matter were formed above them. These in turn have been covered with later deposits, and the pressure on them has gradually hardened these vegetable masses into the substance known as coal. Places where coal has been found in this way are called *coal beds*, and the different layers found in them are known as *seams*.

§ 125. Coal beds are widely distributed over the north temperate zone, especially in Western Eurasia, and across the Continent of North America; and there are also coal beds in China and Australia. Our own island is very rich in them, but by far the most extensive are to be found in the United States.

In some of these beds the oxygen and hydrogen, which form with carbon the material of which coal is made (since it is of vegetable origin), have escaped in the form of gases, leaving the carbon almost pure. This is known as *anthracite coal*, and it is specially valuable for 'smelting,' about which we shall learn something in the next section. It is also much sought after for war ships, because, as well as giving greater heat than other kinds of coal, it makes very little smoke, and so does not allow a ship to be so easily seen from a distance. The coal, on the other hand, which we usually burn in our fires has kept much of its oxygen and hydrogen, and is called *bituminous* coal; it lights more easily, and gives out a brighter flame than anthracite; it is from this, too, that *coal gas* is made, and some, which has a very large proportion of oxygen and hydrogen, supplies us with oils, such as *paraffin*.

§ 126. *Iron* is the most widely distributed of all the metals except aluminium, and, indeed, comes fourth in the list of the elements which are most abundant in the earth's crust (§ 29). We know that it is present in all soils, for we have seen that it is necessary to the growth of plants (§ 95), and it is the compounds of iron and oxygen, such as the one which makes what we call 'rust,' that gives to so many rocks their warm colour.

These compounds of oxygen and iron are often found in masses, and are then known as *iron ore*; sometimes the ore is mixed with carbonates or with clay. In either case, the iron is got from it by *smelting*—that is, by bringing it to a great heat together with carbon, which has the effect of removing the oxygen, and leaving the iron as a hard substance known as *pig iron*. Formerly, wood-charcoal was used to supply the carbon, and it is to this that the destruction of most of our forests is due; now, coal is used in all countries where iron is manufactured on a large scale. We cannot enter here into the details of the further process of smelting; though on them depend the important differences between *cast iron* and the different kinds of *steel*.

The chief beds of iron are marked in the chart, though there are, of course, many smaller ones. Besides what we have in our own country, our supplies come chiefly from Spain and Norway.

§ 127. Other metals used in manufactures of various kinds are copper, tin, and lead.

Copper is more easily smelted than iron, and when mixed with a little tin forms *bronze*, which we have already seen was the metal in use among mankind before iron (§ 107). Our so-called 'copper' coins are made of this compound. Another important compound of copper is *brass*, which is made by mixing it with zinc. Our supplies of copper come chiefly from Spain and the United States, but there are large deposits in Russia, Australia, and elsewhere.

Tin has been mined in Cornwall from very early times, before the coming of the Romans; now, however, it is mainly got from South America and the Malay peninsula. It is also found in various parts of Europe.

Lead is found in Spain and elsewhere in Europe, including our own island; there are also mines in both North and South America.

§ 128. The 'precious metals,' as they are called—gold and silver, have long been used among the more civilised peoples for coinage, as well as for ornament. *Gold* is found in a great variety of places, as our chart shows, and also in very different forms and surroundings; of these we may mention two of the most important. First, river beds, either those still existing as such, or those of former ages, which may now be buried beneath other strata of rocks, or have been upheaved, and form the tops of hills and mountains. In all these the gold is found pure, either in solid lumps called *nuggets*, or as a fine dust. Such a bed is known among miners as a *placer*, and the gold dust is separated by 'washing' the sand and mud in which it lies in a current of water strong enough to carry them in suspension, but allowing the heavier gold particles to sink to the bottom. Secondly, it is found in 'veins' of solid rock, called *reefs*, mixed with other minerals, and from these it is extracted by first 'crushing' the masses of rock containing it, and then removing the other minerals by different chemical processes. The great gold-producing regions are California, Australia, South Africa, and Northern Canada.

Silver is mainly found on the western side of Central and South America, but there are large mines also in the centre of the United States, and in Russia.

§ 129. In the shallower seas, especially of the north temperate zone, immense quantities of fish are caught, and form an important part of the food of the people in those regions. The modern improvements in our means of transport enable 'fresh' fish to be carried to places far from the coast; while some of the commoner fish, such as *haddock* and *herring*, are dried and 'cured,' in which state they can be kept for a long time.

The coasts of the British Isles are specially rich in these fish as well as in *mackerel, ling*, and many others. *Cod* is chiefly got from the famous 'banks' of Newfoundland, and is also found off the shores of Iceland and Norway. There are also large mackerel and herring fisheries on the east coast of North America.

Among river fish, the most important is *salmon*, which abounds in the rivers in the west of North America, as well as in those of Norway. *Sturgeon*, from the roe of which caviare is made, are found at the mouths of the rivers which flow into the Black Sea and the Caspian.

Whale fishing is of less importance now than formerly, since other kinds of oil have taken the place of that derived from its 'blubber'; but it is still carried on in the Arctic Ocean and the Southern Pacific, where the *sperm whale* is found, which gives a more valuable oil.

Questions on Chapter XIV.

1. What is the chief product used in the manufacture of fabrics? Give any particulars you can of its cultivation.
2. Mention the chief drinks made by infusion, and state the principal regions of their origin.
3. Give some idea of the results of fermentation. What substances ferment naturally, or can be made to ferment?
4. Give some account of the origin of coal.
5. What is meant by 'smelting'?
6. Mention some regions where iron, and some where tin, are found.
7. Which are the chief gold-producing regions?
8. Mention some of the more important fisheries, and state where they are chiefly carried on.
9. Explain the expressions: infusion, distilling, anthracite, pig iron, brass, placer.

CHAPTER XV

THE EMPLOYMENT OF NATURAL PRODUCTS

§ 130. In the last two chapters we have considered, under the head of 'natural products,' some of the chief materials cultivated by man or got by him from the earth, in the form of plants, animals, or minerals; and we learned something of the natural advantages of climate and soil needed for the production of each. But these products, except such as are used for food, have as a rule to be manufactured into useful things, before they can satisfy our wants. Thus, for example, the cotton seeds have to be prepared and spun into yarn, then woven into fabrics, before they can be used to wear. Such products before they are manufactured are known as *raw material*. Even in the case of those used for food, or, as they are called for convenience, *food-stuffs*, a certain amount of manufacture is usually required; thus the wheat is ground into flour before we eat it, and meat, if it is to be taken a long distance, must first be prepared and then frozen or salted. We have, then, to consider the natural advantages required for turning raw material to use by manufacture—in other words, *the conditions favourable to industries*.

Again, in order that these products, whether manufactured goods or food-stuffs, may satisfy the wants of people in various parts of the globe, they must be sent to the places where they are wanted, or as it is called *distributed*; so we shall next have to consider how this is done—that is, the *methods of transport*; and finally we must try to understand something of the system by which one kind of product is exchanged for another—which is called in one word *trade.*

§ 131. It might naturally be expected that industries would always be carried on near the spot where the raw material was produced, and this is often the case Porcelain, for example, is made in Southern China, and crockery in Staffordshire, because the special kinds of earth required for their manufacture are found in these regions. But we have seen that the more important industries are dependent on coal (§ 107); and it is almost always easier to take the raw material to places where this is abundant, rather than the coal to places where the material is produced. Consequently *we shall look for the chief industries of the world in those regions where coal is plentiful*; and so it is very important to know the position of the main coal beds in various regions.

It is true that formerly *water-power* was much used for working machinery; so that you will often find flour mills driven by water wheels still, and the great woollen factories of Yorkshire grew up there largely on account of the number of streams which could be made use of in this way. Also it is probable that in the future water-power will be very much used for making electric power, to take the place of steam for many purposes. But at the present time what was said above is none the less true, that the chief industries are dependent on coal.

§ 132. Another natural condition affecting industries is climate. In a tropical, or very warm climate, people are rarely strong and vigorous enough to stand the severe labour required in most manufactures; and as in such climates they can usually live comfortably on the results of the natural products of the soil, or such as can easily be got by its cultivation, they have no inducement to turn their attention to manufacture. This is not the case in colder regions, and consequently people in these latter are more inclined to bestir themselves, and have also the strength to make up for their less fertile soil, by greater attention to various kinds of industry. *We shall therefore* *find these in the cool temperate, rather than in the tropical regions.*

§ 133. But it is clear that none of these advantages would be of any avail if the material could not easily be brought to the place of manufacture, and if the things manufactured could not easily be taken wherever they were wanted, so that a necessary condition of any industry is that it should be in a spot easily reached. In this connection it is important to bear in mind that transport by water is much easier, and therefore cheaper, than transport by land. You will have no difficulty in realising this if you have ever seen a horse towing a barge loaded with coal, and if you think for a moment how many horses it would take to drag the same barge along the road, or even a railway line, if it were on wheels. That is why it was thought worth while to spend millions of pounds in making a canal which would enable ships from across the Atlantic to bring their cotton straight to Manchester, instead of having to unload it at Liverpool, thirty miles away. So, then, *industries tend to grow up near to some harbour on the sea-coast, or on the banks of a navigable river.* One great reason why there is such an immense cotton industry in Lancashire is that the material can so easily be imported from America and taken to places where coal is abundant, and when manufactured, the fabrics can as easily be exported to all parts of the world. Our great iron industries, again, owe their success largely to the fact that both iron and coal are found near the sea-coast, so that coal can easily be brought to those places where there is iron ore ready to be smelted, and the iron and steel when made can be taken wherever they are needed for other manufactures. On the other hand, we have seen that there is abundance both of coal and iron in the centre and east of Russia, and one reason why it is so little used for industries is the difficulty of transport to other regions.

§ 134. Of methods of transport, by which the distribution of productions is carried out, we have already mentioned some (§ 114); and, broadly speaking, it may be said that till he middle of last century transport by sea was dependent on wind, and transport by land on draught animals. Since that time the sailing vessels have gradually been displaced by *steam-ships*, and the draught animals by steam *locomotives*; both of which make a further demand on our coal supplies. At the same time much inland transport is carried on by water, by means of *canals* connecting the rivers.

Now the steam locomotives usually run, as you know, on rails, which enable them to go faster and draw much greater loads than they could on a road; so in any region it is most important to know something of these railed tracks, or *railways*, on which the connection between the different parts of it so largely depends. In fact they may be compared to the veins and arteries through which the circulation of the blood is kept up in our bodies. When any new region is settled by civilised people, one of their first objects is always to make a railway through it, so as to bring the different parts of it into touch with one another, and from what was said in the last section you will see that such a railway must have a great effect on its products and industries.

§ 135. But we found, you will remember, that transport by sea was much easier and cheaper than that by land; and though it is not quite so safe, on account of storms and fogs, nor quite so fast as that by rail, it has this further advantage over the latter that it is not dependent on a specially made track. A ship can steam anywhere over the sea without any labour being spent in preparing its pathway or keeping it in order; and without any fear of its becoming overcrowded with traffic as a railroad may. And so *the sea must be regarded as a great natural highway, which connects rather than separates distant regions.* Our own empire, for example, looks on a map much less compact than the Russian Empire; but in fact its parts are much more closely connected than are those of the latter.

To sum up, then, what we have learned about industries and transport. The chief conditions required by industries are: first, abundance of coal, or sometimes of water-power; second, a healthy and bracing climate; thirdly, easy communications with other regions. Of the means of transport by which this communication is kept up, those by water are for several reasons better than those by land.

§ 136. It will be more difficult to get a clear idea of the system by which these various products are exchanged for one another, but it is very necessary to do so if we are to understand much of the geography of various regions. We have seen that different regions are suited for the production of different things; each, then, exchanges so much of its products as are not required for its own use for the products of other regions. Thus we learnt that a large part of Australia was very well adapted for rearing sheep; but it would be useless for men to do so on a large scale unless they could get something in exchange for their sheep or their fleeces. Again, it would be equally useless for men to grow millions of bushels of wheat in Canada unless they could send it elsewhere and get something in exchange for it; and this is equally true of all regions: whatever is sent from that region to any other, or, as it is usually called, *exported*, is really exchanged for something that is being, or has been, *imported* into that region. And this exchange is what is called, as we saw, trade.

Now it is obvious that this exchange is not a simple affair at all. The sheep farmer in Australia supplies wool for the cloth-weaver in Yorkshire; but the cloth-weaver cannot supply him directly with, let us say, wire fencing, tea, and a cottage piano, which were perhaps what the farmer wanted in exchange for the wool. The exchange is really carried out by another class of men called *merchants*, and also by brokers and bankers; and these, with the people they employ to help them—clerks, warehousemen, and others—form a large part of those engaged in carrying on the world's trade.

§ 137. You will notice that so far we have said nothing about 'buying' and 'selling'; and it is most important that you should realise that these are merely the means by which the exchange of goods is made. Suppose, for example, I am a bootmaker and you want a pair of boots: I give you a pair in return for a sovereign, or, as we generally say, sell them to you for a sovereign. But I cannot eat the sovereign or wear it, or use it for any ordinary purpose except ornament; and I only take it instead of the boots because I know that wherever I go I can exchange my sovereign for any thing, or things, I may want up to the value of the boots. So then it may be described as a *medium,* or means, *of exchange.*

But in the trade that is carried on between different regions, money is no longer used as a medium of exchange, but only to express what the value of a certain amount of any product would be if it were paid for in money; and so here it is only a *standard of value.* If, for example, our cloth-weaver in Yorkshire wants some more wool, he arranges through a merchant to take a quantity from the sheep farmer in Australia, valued, let us say, at 1,000*l.*, and pays the merchant for it. The merchant does not send the 1,000*l.* to Australia, but a 1,000*l.* worth of goods instead; and arranges through bankers or brokers, and through other merchants, that the value of these shall be paid to the farmer. It would be difficult to explain here exactly how all the arrangements are made, but at least you can see that the 1,000*l.* was used to measure the value of different productions in England and in Australia, so that they could be exchanged for one another.

§ 138. Now each of these three stages by which natural products are made to satisfy human wants—that is, manufacture, distribution, and exchange—involve the existence of *towns.* In every region where people are at all civilised, there are, as you know, and always have been, certain spots where they tended for one reason or another to collect together; and during the last century this tendency has become very much greater, so that almost all large towns are growing, and there are now as many as a dozen towns in different parts of the world each having more than a million inhabitants. Let us see if we can get hold of some of the chief reasons which have caused people to come together in towns.

First, there is the *market town*, where people engaged in cultivating the land meet to buy what they want for ordinary use, and sell their produce to dealers or merchants. In each district one of these market towns will usually become more important than the others, as a recognised centre for dealers of various kinds, and here they will store the produce they buy, ready to send wherever it is wanted. Here, too, will be the best shops, where the greatest variety of useful things are stored ready for sale. For such a *commercial town* good communications are necessary; and if it is an old one, it will probably be found on the banks of some river; in any case it will be on a railway line, and most probably at a point where several lines join. Most of our 'county towns' are of this kind, such as Peterborough or Gloucester; and on a larger scale are Frankfort in Germany and Winnipeg in Canada.

§ 139. Again, a town may for some reason be specially adapted for certain manufactures, as are Burton and Munich for making beer, on account of the quality of the water; or Middlesbrough, Liège, and Pittsburg, for smelting, because the coal and iron ore can so easily be brought together there; and when once a town has got a name for a certain industry, those engaged in that industry tend to collect there, partly to take advantage of the name, and partly for convenience; so that Sheffield is famous all the world over for its cutlery, Lille for its fine yarn. Then, too, many different manufactures require much the same kind of labour and appliances, as well as the same general conditions about which we spoke before, so that *manufacturing towns* tend to grow and attract varied industries; such, for example, are Birmingham, Leeds, Warsaw.

Other towns owe their importance to a commanding position with regard to transport. Chief among these are, of course, the great *sea-ports*, where goods are loaded for transport by sea, and others unloaded ready for transport by land. A large port will almost always become a great commercial town as well, since it is naturally used as a depot for storing the goods for export, and those that are imported. Liverpool, Hamburg, and New York may be taken as examples of the great commercial ports.

§ 140. Last of all, in each independent region or country there will be one town, known as the *capital*, where the government is carried on, and where the chief courts of justice are held; the sovereign, if there is one, will usually hold his court there; and such a town will attract a great many people who are free to live where they please, and become a centre of pleasure and amusement, and often also of learning; in a word, it will become a great *residential town*. Paris and St. Petersburg are excellent examples of such residential capitals. Further, such a town is almost always the centre of the railway communications of the country, and tends for many reasons to become a great commercial centre as well; and as we compared the railways to the veins and arteries of the human body, we may compare the capital to its heart.

London is, as you know, the largest town in the world, and it owes its immense size to the fact that it combines in itself all the elements we have mentioned as contributing to the greatness of a town. It is a market, a depot, a commercial centre, a manufacturing town, a sea-port, a residential town, the starting point of the chief railways, the seat of the government and of the court.

Questions on Chapter XV.

1. Give the main conditions on which industries depend.
2. Why is transport by sea preferable to that by land?
3. What are the chief methods of overland transport? Show the importance of each.
4. Explain the expressions: raw material; distribution; trade; medium of exchange.
5. Why is money called a 'standard of value'?
6. What different kinds of towns are there Give an example of each.

CHAPTER XVI

RACES OF MANKIND

§ 141. You may remember that we spoke of the rocks which form the earth's crust as a book from which something might be learned of its history (§ 42); it is this same book which tells us the little we know of our earliest forefathers. The first traces of mankind to be found in it take us back many thousands of years, but they do not throw very much light on his origin; and all we can say for certain about this is that he must have 'developed' from a kind of ape, perhaps not unlike some that are to be seen in the Zoological Gardens now. Of the early history of mankind we have already learned something in Chapter XII., especially so far as it has to do with his control of nature. All this belongs to the science of *Anthropology*.

We must now find out the chief races into which human beings are divided; and this the science of *Ethnology* will tell us, though how they came to be so divided is another problem which we cannot solve. We can, however, learn the most important characteristics of each race, and in what parts of the globe each is to be found; for this is the part of ethnology which concerns us most.

§ 142. Far the greater part, if not actually the whole, of mankind belong to one of four great groups, which can easily be remembered from the colour of the skin in each case, as the *black*, the *brown*, the *yellow*, and the *white* races. There are many other ways of testing the difference besides that of colour; we shall only mention some of the chief ones.

The black, or *negro*, races are distinguished by woolly or frizzy hair; the yellow, or *Mongoloid*, races by straight or lank hair; the white and brown races by wavy or curly hair. Our hairs, though they look so slender, are really hollow tubes; and the differences just noticed arise from a difference in the form of this tube. If you cut one of each kind across and look at it under a microscope, you would find that the lank hair was round, the curly hair slightly oval, and the frizzy hair still more so, as in the third illustration of fig. 45.

Again, if you were to take a hatter's measure, so as to get the shape of the skull round the top, you would find that the negro's was much longer in proportion to its breadth than that of a white man, while a Mongolian's would be much shorter; that is, the skull would be rounder.

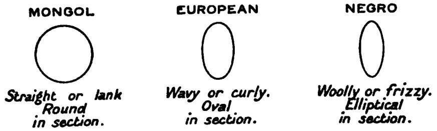

MONGOL
EUROPEAN
NEGRO
Straight or lank. Round in section.
Wavy or curly. Oval in section.
Woolly or frizzy. Elliptical in section.

FIG. 45.—FORMS OF HUMAN HAIR
(*After E. B. Tylor.*)

A fourth test would be the projection of the jaws—that is to say, whether they stuck out beyond a line going straight down from the base of the forehead. This you would find most marked in the case of the negro, next in the brown races.

We may take, then, as the chief tests of race groups, colour of skin, form of hair, shape of skull, position of jaws; others will be mentioned in dealing with some of the more doubtful races. For you must remember that these differences are not nearly so great as are to be found between different species of apes, or of many other animals, nor so great as to prevent any of the human races from uniting with one another, and so forming a mixed race; and this has happened to such an extent that it is not always easy to say to which group any particular people or tribe belongs.

§ 143. Next we must see where there is to be found what may be called a good specimen of each group, and then over what regions the same type can be traced. The pure negro is to be found on the coast of Guinea, in Africa. His skin is almost black, and has an oily appearance; the hair is quite black and, as we saw, woolly. The skull, as well as being long, is very thick, and the jaws project very much. Further, the eyes are large and round, the nose flat and broad with large nostrils, the lips thick and turned outwards, arms very long in proportion to the body, legs very thin especially at the calf, and the heel sticks out noticeably behind the foot. The negro is by nature the least clever of all the great race families, having the smallest actual amount of brains. In disposition he is cheerful and pleasure-loving, and is very easily carried away by impulse.

Races all having more or less of the same characteristics inhabit the whole of Central and Southern Africa, and a type very strongly resembling them is found again in New Guinea and the islands known as Melanesia. The people of this type are called Papuans, whom you may regard as ‘distant cousins’ of the true negro. Of course those negroes found in the south of the United States were brought there from West Africa as slaves.

§ 144. For our type of the brown races we must go to Australia. Here we shall find men of a dark-brown colour, with black wavy hair, not woolly like the negro's and Papuan's; broad but not flat noses, rather projecting jaws, and big lips. When we try to trace the brown man in other regions it becomes more difficult. There is no doubt they once peopled India, and the lowest class, or ‘caste,’ called ‘coolies,’ especially in the south, certainly belong to this group. They are also to be found in Madagascar. The brown races are little, if at all, superior to the negroes in intelligence.

§ 145. Of the four great families the most widely spread is the yellow, or Mongolian. We may take as a typical specimen a Chinaman, and have already noticed his colour, and his black lank hair. Other peculiarities are the slanting almond-shaped eyes, short stature, and broad but not flat nose. This type is found almost pure throughout China and Japan, and among the Tartars, Calmuks and Thibetans of Central Asia; and in a less marked form among the Finns and Lapps of Northern Europe, the Magyars of Hungary, and the Turks; while Mongolian blood can be traced in some of the white inhabitants of Russia. But even this does not bring us to the end of the Mongolian stock. The Malayans, who inhabit large parts of the East Indies, as well as the Malay Peninsula itself, have many points in common with the yellow races, and may very likely be an early mixture of these with the brown races. Besides this, the native population of both Americas, from the north of Canada to Cape Horn, seem to have been originally an offshoot of the Mongolian family.

Unlike the black and brown races, the Mongols are for the most part highly intelligent, as the position of the Japanese among the great nations well shows; while those who lived in China were quite one of the first peoples to become civilised (§ 106).

§ 146. Last of all we come to the white races, to which we ourselves belong, with their high foreheads, sharply cut noses, and well-developed bodies; and here we must make a distinction between the *fair whites* of the north and the *dark whites* of the south. The first are distinguished by their great size, their flaxen or straw coloured hair, and blue or steel grey eyes. Such men are chiefly to be met with in Norway, Sweden, and Denmark, in the north and east of England and Germany, and in Northern Russia. Perhaps the best representatives of the dark whites are to be found among the Irish; but they extend all through the south of Europe, along the north of Africa, from which it is probable that they originally came, and into central Eurasia as far as India. Here they seem to have partly driven out and partly mixed with the brown races who, as we saw, once peopled it. Again, the dark and fair whites are so mixed or blended that it is almost impossible to separate them, and say to which of them a particular people belongs.

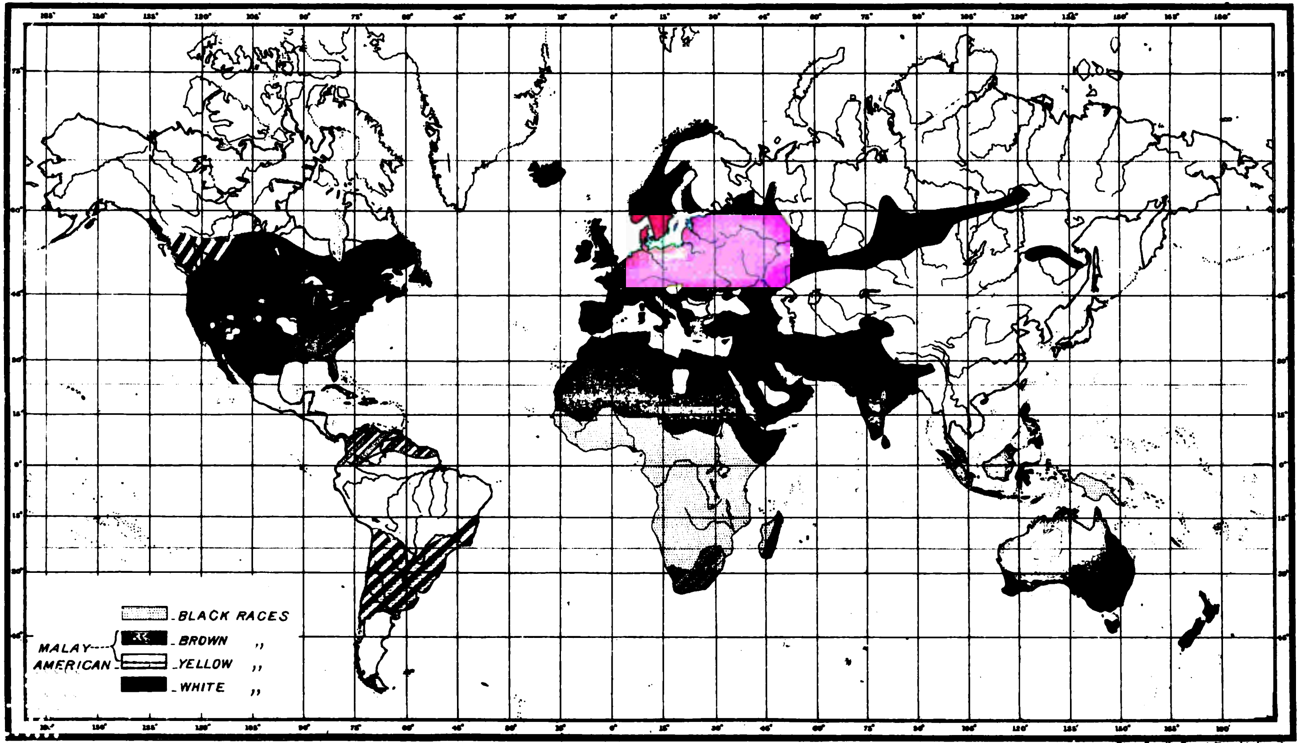
All the most civilised nations of the present day, with the exception of the Japanese, belong to the white races, and occupy the western end of the Eurasian continent, which we know as Europe, forming a very closely connected group. They owe their proud position not so much to superior intelligence as to the energy and determination which are one of their chief characteristics.

This chapter is no doubt a little confusing to you, but if you study carefully the map in which these race groups are given in colours, with the blending from one to another, you will soon get hold of at least the main facts.

Questions on Chapter XVI.

1. Give the chief tests of the great race groups of mankind.
2. Where are the negro races to be found?
3. Where are the Mongolian races to be found?
4. What do you know of the white races?

RACES OF MANKIND.



London : Edward Stanford, 12, 13 & 14, Long Acre, W.C.

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D. CARTOGRAPHY

CHAPTER XVII

READING AND MAKING OF MAPS

§ 147. BEFORE passing on to regional geography, it is very necessary that we should understand something of the methods by which various parts of the globe, and even its entire surface, are represented on what are called *maps*. If you wanted to know something about any region, the first thing you would probably think of doing would be to look at a map of it, and the amount of information you get from studying this would depend, first, on what there was in the map, and second, on your power of reading what was there. Let us see, then, what sort of things a map can tell us, and how far the information it gives is correct.

Whatever kind of a map we have, it will give the *outline* of the region—that is to say, either the line where the land sinks into the sea, or *coast line*, or the line where it joins on to other regions, called its *boundary line*. Thus, the map of Great Britain shows a coast line all round it, since it is an island; but if we take the map of England alone, it will show a boundary line on the north, where it joins on to Scotland, and another on the west, where it joins on to Wales.

We shall carefully notice with regard to the coast line, whether it makes a fairly regular line or whether it winds in and out very much, or, in other words, is what is called *indented*, or 'toothed'; for we already know (§ 80) that the most indented coast line will probably be found on a rocky coast and facing a deep sea. The coast line of Great

Britain is obviously more indented on the west than on the east side, so we shall expect that the sea will be deeper, and the land more rocky on that side.

§ 148. Our map also shows some of the lines of latitude and longitude. What these are you already know from Chapter III., and their value for us is, first, to show in what part of the globe the region represented on the map lies; and second, to give some idea of its size as compared with other regions. Thus we notice that Great Britain lies between lat. 50° and 59° N.—that is, towards the north of the north temperate zone; and that it takes up from north to south not quite one-twentieth of the distance between the poles.

The question of size relative to other regions is important, because we are apt to be misled by maps of the same size being used to represent areas of very different size. If, however, we look carefully at the number of degrees of latitude and longitude covered by each, we shall not lose sight of this difference, and shall know that the maps are drawn to a different *scale,* as it is called. But the actual scale ought also to be given on each map—that is to say, the exact extent to which it must be magnified in order to get the actual size of whatever is represented on it. Thus our map of Great Britain is on the scale of 1 to 6,336,000, so that one inch on the map is equal to 6,336,000 inches of the country, or 100 miles. The same thing is often expressed by saying that the map is on the scale of 100 miles to the inch.

§ 149. Next, any map will almost certainly mark the course of the larger rivers, and from these also we can gain some information. In our map of Great Britain let us draw a line between those that flow eastward and those that flow westward, in such a way as not to cut through any of them; this will give us the *water parting*—the backbone, so to speak, of the country (see § 65). We see that in our map this runs almost due north and south, and is well to the west of the country, from which we gather that the greater part of it slopes eastward. Further, we shall have gained some idea as to where the highest ground lies; but it will be more

MU

satisfactory if this is clearly marked, for the course of the rivers only enables us to make a rough guess at it.

One way of showing the slope of the region more clearly is by what is called a *vertical section.* Let us imagine that along the dotted line on our map a deep cut is made straight down, or 'vertically'; and that the land on one side of it is pared away down to sea-level, leaving the other side standing sheer up; this side will then show the height of the land along the dotted line above sea-level. The only difficulty is one which might not perhaps occur to you. The length of the dotted line, as you can calculate from the scale given, is 233 miles; and the highest point in the vertical section is only 2,929 feet—that is, about $\frac{1}{420}$th of the length. If, then, we drew the vertical section 'to scale' the variations of height would be so slight as to be invisible; so we will exaggerate the vertical lines to fifty times their proper size; and we shall then have the vertical section given below (fig. 46).

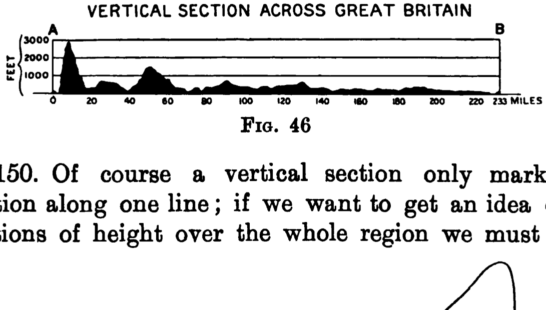
VERTICAL SECTION ACROSS GREAT BRITAIN

FIG. 46

§ 150. Of course a vertical section only marks the elevation along one line; if we want to get an idea of the variations of height over the whole region we must use a

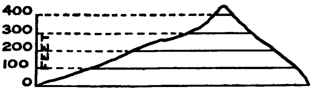

FIG. 47.—MOUNTAIN ELEVATION

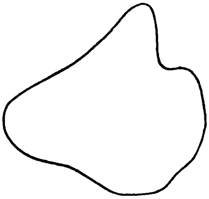

FIG. 48.—CONTOUR OF MOUNTAIN

different method. Fig. 47 represents a hill rather over 400 feet high; let us imagine a line drawn round it at a height of exactly 100 feet: we shall then get an outline like that in fig. 48. Next we will draw a second line where it is exactly 200 feet high; then one at 300 feet, and lastly one at 400 feet. We have now four rings, known as *contour lines*, one inside the other, as given in fig. 49, and if we know that each represents a rise of 100 feet, it will not be difficult to tell the height of the hill. Besides this they will give us a better idea of the shape than we got from fig. 47. Thus we can see now that it has a long spur stretching away from us, which was not visible in fig. 47. Also it is obvious that the more gradual the slope, the further the contour lines will be apart; and, therefore, the nearer they are together, the steeper will be the slope they represent; so we can tell at a glance from fig. 49 that the hill slopes more steeply up on the right-hand side than on the left, and that the slope facing us is more even than that on the opposite side. This is the only method by which the elevation, as it is called, of any large region can be accurately shown; and you must accustom yourselves to being able to read the meaning of these lines easily. It may help you to do so if you try and imagine, as you look at our second map of Great Britain, that the sea has risen exactly 200 feet. The coast line would then be where the first contour line is, and the sea would cover up all that part of the map which is left white; if it rose 300 feet more, it would reach the second contour line, and cover up all the lightest brown shading, and so on. But in representing actual hills or mountains, such as the one in fig. 47, it will be well to use a certain kind of shading

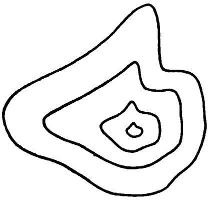
FIG. 49.—SERIES OF CONTOUR LINES

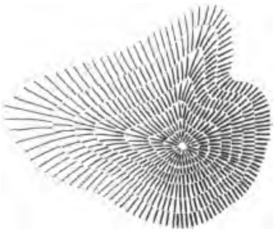
FIG. 50.—HACHURE DRAWING OF SAME MOUNTAIN.

as well. Thus our original hill might be drawn as in fig. 50. This is known as *hachuring*, and is one method of representing a comparatively small mountainous region.

§ 151. We have now learnt something of what an ordinary map can tell us, and we must next see how far what it tells us is accurate. This will depend first of all on its size in proportion to the area represented. There is no need to explain this, for you will see at once that on a map of England, for example, you cannot give as accurate a plan of London as in a map of the same size occupied by London alone.

When, however, we come to deal with very large regions, such as the continent of Eurasia, and still more when we try to represent the whole world on a map, we are met by a difficulty of another kind, namely, that it is impossible to represent the surface of a sphere, or even a hemisphere, on a surface that is flat. This you can easily prove by taking a cricket cap, which is roughly a hemisphere, and trying to smooth it out flat on the table.

First, then, let us take a photograph of a globe from one side of it, and see how far the photograph correctly represents a hemisphere (fig. 51). We know that the distance from the equator to the poles is everywhere the same, and that all the lines of longitude are equal; but in our photograph these get greater and greater as we go from the middle to the edge of the globe. Consequently the same region will appear much longer from north to south at the edge of the globe, than it would if we turned the globe round so that the same region were in the middle. Again, you will notice that the lines of longitude come much nearer to one another at the edge than they are in the middle, and so any region will appear narrower from east to west as well as longer from north to south than it does in the middle. Clearly, then, this does not give a very accurate picture of the shape of the oceans and continents.

§ 152. It is true we cannot do away with this error, but we can at least prevent it from all falling in one part, by the following method. On the straight line representing the

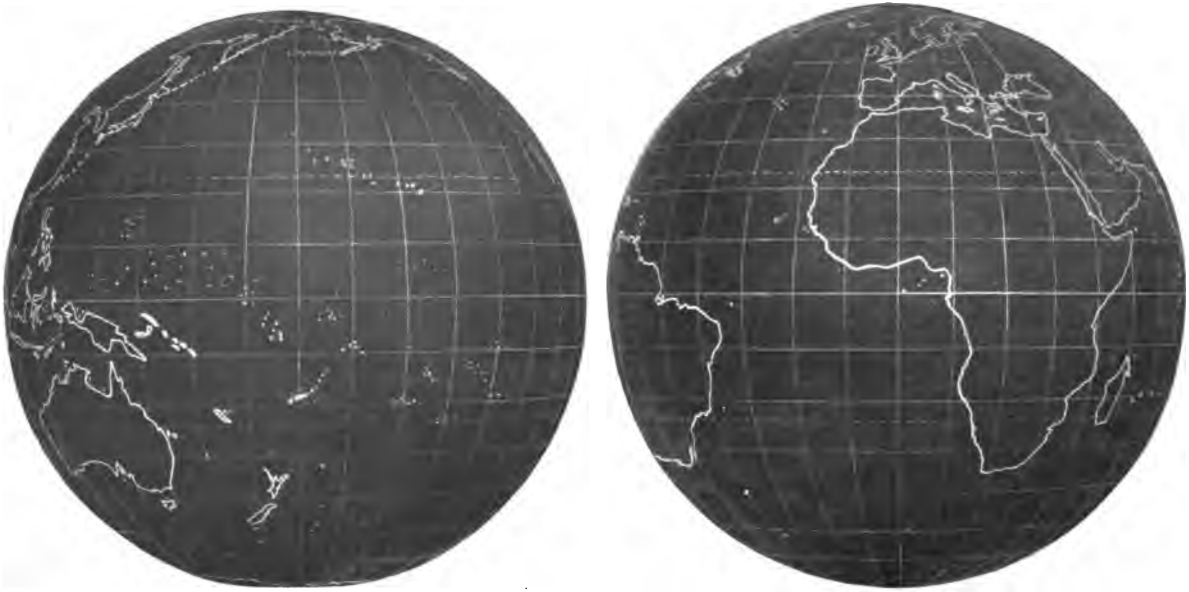

FIG. 51.—PHOTOGRAPH OF THE HEMISPHERES

equator we will mark off the degrees of longitude at equal distances, and draw the lines through those points to the two poles, making them of course curve more as they approach the edge of the circle. Next we will mark off the degrees of latitude in the same way along the straight line joining the poles, and mark them off also along the two half circles at the edge. The parallels of latitude will then be represented by a series of lines passing through these points, and becoming more and more curved as they approach the poles (fig. 52). All that can be said for this way of drawing the hemispheres is that no part of them will be quite so much distorted as it was before, and that the error is more distributed over the whole; but our lines of longitude are still unequal in length, and those of latitude are no longer parallels.

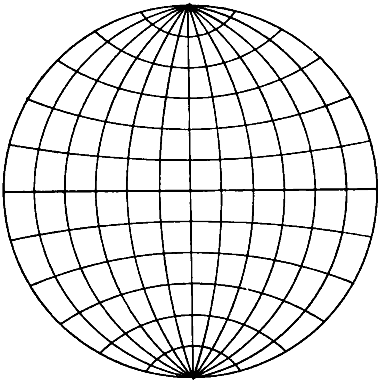

FIG. 52.—GLOBULAR PROJECTION

§ 153. Another method is to make each of the poles the centre of a hemisphere, with the lines of longitude radiating out from them like spokes of a wheel, and the parallels of latitude drawn as circles at equal distances from the pole at the centre. You will see at once that the further we go from the poles the more the distances from east to west become exaggerated; so this method or *projection* is only used in representing regions in the arctic and temperate zones (fig. 53). There are several more of these projections, each having some advantages over the others, but these two will enable you to understand the difficulty, and the sort of way in which cartographers try to get over it.

And now if we want to represent the whole globe on one map, as we have several times had occasion to do already, we have to make use of a projection which distorts things even more than the first one we mentioned. We must imagine the globe as a cylinder, instead of a sphere, which is unrolled and laid out flat. Then the poles will be represented by lines each as long as the equator, and all the lines of longitude will be parallel. It is clear, then, that the nearer we get to the poles the more the breadth of any region from east to west will be exaggerated, and in order not to distort the shape of these regions so much, the lines of latitude are drawn wider apart to correspond to the exaggeration of the distance between the lines of longitude; the result is, of course, that the further it is from the equator the bigger any place will be in proportion to its actual size. But this method has another advantage besides that of giving us the whole globe on one map—namely, that a

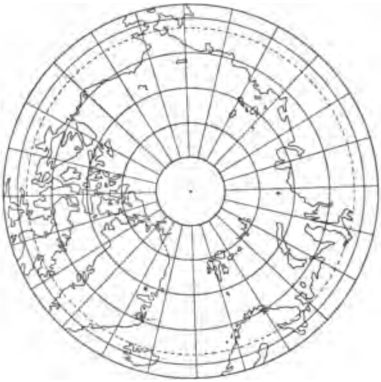

FIG. 53.—POLAR PROJECTION

straight line ruled on such a map represents practically a single or uniform direction, whereas a straight line drawn on any of the other projections we have considered will represent a curved or shifting direction on the surface of the globe. That is why this kind of map, known as *Mercator's projection,* is always used in making nautical charts—that is, maps to enable sailors to trace their direction at sea.

Questions on Chapter XVII.

1. Of what use are the lines of latitude and longitude on a map of any region?

2. Explain what is meant by each of the following expressions:

   (*a*) The scale of a map.
   (*b*) An indented coast line.
   (*c*) A vertical section.
   (*d*) A contour line.
   (*e*) Hachure shading.
   (*f*) A projection.

3. Describe the method of drawing a map on Mercator's projection.

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